GEOCHEMICAL EXPLORATION OF INUIT SOILSCAPES IN NORTHERN LABRADOR

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ABSTRACT

The past Inuit people of northern Labrador had a variety of effects on their landscape. However, there is an absence of archaeological research addressing their inadvertent influence on the soil's chemical record. Here, I contribute to this type of research by investigating the geochemical characteristics of soils from Inuit winter dwellings at Iglosiatik Island, Nachvak Fiord, Komaktorvik Fiord, and Big Head, northern Labrador. My research at these locations compares the geochemical compositions of soils from several dwelling spaces, adding a geoarchaeological perspective to the study of spatial organization within Inuit winter dwellings. Spaces in these households had socially prescribed and proscribed functions, and the *habitus* associated with these taskscapes modified the soil's chemical record.

The geochemical characteristics of soils from dwelling floors, sleeping platforms, lamp stands, storage niches, entrance tunnels, and refuse disposal areas were compared with adjacent non-habitation areas to determine their degree of anthropogenic alteration. The elemental compositions of these soils were measured using x-ray fluorescence and inductively coupled plasma-mass spectroscopy, while pH, reduction-oxidation potential, and total dissolved solids were determined using electronic meters. Compared to their respective control samples, soils from the tested dwelling spaces were more acidic and had elevated concentrations for a variety of elements. Independent-samples t-tests and principal components analysis revealed that the tunnel alcove, middens, sleeping platforms, lamp areas, and entrance tunnels have characteristic increases in distinct suites of elements.

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LIST OF ABBREVIATIONS

HbCh-1: Iglosiatik 1 Archaeological Site, Labrador
IgCx-3: Nachvak Village Archaeological Site, Labrador
IhCw-1: Komaktorvik 1 Archaeological Site, Labrador
IiCw-1: Big Head 1 Archaeological Site, Labrador
NkRh-3: Pearce Point Archaeological Site, Amundsen Gulf
RbJr-1: Porden Point Archaeological Site, Devon Island
IdCr-2: Ikkusik Archaeological Site, Labrador
GiCb-1: Avertok Archaeological Site, Labrador
IdCr-1: Tuglavina Archaeological Site, Labrador
g: Gram
mg: Milligram
m: Meter
cm: Centimetre
mm: Millimetres
m^2: Square Meters
^{0}C: Degrees Celsius
ml: Millilitre
g/l: Grams per Litre
mV: Millivolts
ppm: Parts Per Million
mg/kg: Milligrams per Kilogram
N: Molar/Molarity
ton/in^2: Tons per Square Inch
µS/cm: Microsiemens per Centimetre
Å: Angstrom
keV: Kiloelectron Volt
µm: Micrometers
pH: Acidity/Alkalinity
Eh: Reduction-Oxidation Potential
TDS: Total Dissolved Solids
EC: Electrical Conductivity
XRF: X-Ray Fluorescence
ICP-MS: Inductively Coupled Plasma-Mass Spectroscopy
ICP-AES Inductively Coupled Plasma-Atomic Emission Spectroscopy
SPSS: Statistical Package for the Social Sciences
PCA: Principal Components Analysis
ANOVA: Analysis of Variance
Li: Lithium
Na: Sodium
K: Potassium
Rb: Rubidium
Cs: Caesium

Mg: Magnesium
Ca: Calcium
Sr: Strontium
Ba: Barium
P: Phosphorus
S: Sulphur
Cl: Chlorine
Ti: Titanium
V: Vanadium
Cr: Chromium
Mn: Manganese
Fe: Iron
Ni: Nickel
Cu: Copper
Zn: Zinc
Zr: Zirconium
Nb: Niobium
Mo: Molybdenum
Cd: Cadmium
Pb: Lead
Ga: Gallium
Hf: Hafnium
Sc: Scandium
Y: Yttrium
La: Lanthanum
Ce: Cerium
Pr: Praseodymium
Nd: Neodymium
Sm: Samarium
Eu: Europium
Gd: Gadolinium
Tb: Terbium
Dy: Dysprosium
Ho: Holmium
Er: Erbium
Tm: Thulium
Yb: Ytterbium
Lu: Lutetium
Ta: Tantalum
Th: Thorium
Co: Cobalt
W: Tungsten
N: Nitrogen
Si: Silica
H^+: Hydrogen Ion

OH^-: Hydroxyl Ion
KCl: Potassium Chloride
AgCl: Silver Chloride
HF: Hydro-Fluoric Acid
HNO_3: Nitric Acid
DTPA: Diethylenetriaminepentaacetic Acid
NH_4F/HCL: Ammonium Fluoride/Hydrochloric Acid
H_2SO_4 : Sulphuric Acid
SO_2: Sulphur Dioxide
SO-2: Soil/Sediment Reference Standard (Podzolic Soil)
PACS-1: Soil/Sediment Reference Standard (Harbour Marine Sediment)
SY-2: Geological Reference Standard for Syenite (Silicate Rock)
SY-3: Geological Reference Standard for Syenite (Silicate Rock)
MRG-1: Geological Reference Standard for Gabbro (Silicate Rock)
DNC-1: Geological Reference Standard for Diabase (Silicate Rock)
W-2: Geological Reference Standard for Diabase (Silicate Rock)
DTS-1: Geological Reference Standard for Dunite (Silicate Rock)
PCC-1: Geological Reference Standard for Peridotite (Silicate Rock)
AGV-1: Geological Reference Standard for Andesite (Silicate Rock)
STM-1: Geological Reference Standard for Sycnite (Silicate Rock))
BHVO-1: Geological Reference Standard for Basalt (Silicate Rock)
BCR-1: Geological Reference Standard for Basalt (Silicate Rock)

CHAPTER ONE

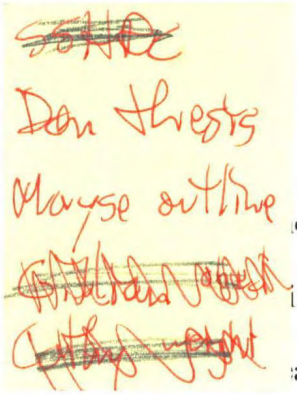
INTRODUCTION

Tasks such as butchering a seal, storing the meat, cooking it, preparing the skin, and disposing of the refuse produce liquid and particulate by-products that are incorporated into soil systems. In Inuit society, these types of practices are likely performed in specific places, which can change the chemical compositions of the soils in those places. For example, varying degrees of P enrichment and decreases in pH deriving from accumulations of anthropogenic organic wastes are useful chemical markers for settlement locations, trash disposal areas, and activity areas, or taskscapes. Essentially, the soils on which human activities are enacted preserve a chemical record of those practices, meaning spatially patterned element concentrations in archaeological soils could reflect socially structured behaviours. Here, I explore the geochemical compositions of soils from Labrador Inuit winter dwellings at Iglosiatik Island, Nachvak Fiord, Komaktorvik Fiord, and Big Head. Specifically, my goal is to determine whether house floors, sleeping platforms, lamp areas, storage areas, entrance tunnels, and middens have distinct geochemical signatures, adding a geoarchaeological perspective to the study of how past Inuit people organized the interiors of their houses. Potential sources for chemical enrichments in soils associated with Inuit houses include tending soapstone lamps, cooking, storing food, preparing animal skins, personal grooming, manufacturing tools, keeping dogs, and disposing of a variety of types of refuse.

This research aims to identify geochemical characteristics that are enhanced on Inuit archaeological sites and whether specific enrichments are associated with particular

dwelling features. If particular Inuit activities produce unique geochemical by-products, the locations where such activities were performed should be identifiable in the soil's chemical record. That is, the association of particular chemical fingerprints with discrete spaces should reflect the performance of different tasks in these socially defined spaces. To strengthen this claim, I address the following questions: 1) Do geochemical characteristics differ between Inuit archaeological sites and adjacent, non-habitation areas? 2) If so, what characteristics are enhanced on the sites? 3) Do house floors, sleeping platforms, lamp areas, storage areas, entrance tunnels, and middens have unique geochemical characteristics? 4) What Inuit activities could have caused any observed chemical enrichments in the tested soils? To answer these questions, soil samples were collected from seven Labrador Inuit winter dwellings and four middens. The colour and texture of the samples are described. The pH, Eh, and TDS of each soil sample are identified using electronic meters. Forty-five elements are measured using XRF and ICP-MS. These are the alkali metals Li, Na, K, Rb, and Cs, the alkaline earth metals Mg, Ca, Sr, and Ba, the non-metals P, S, and Cl, the transition/heavy metals Al, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Zr, Nb, Mo, Pb, Ga, and Hf, and the rare earth elements Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ta, and Th. I focus on the inorganic chemistry (rather than both inorganic and organic chemistries) of the soils because of time and resource restraints. Descriptive statistics, independent-samples t-tests, and PCA will help answer the research questions stated above.

Northern Labrador is an ideal location for studying human influences on soil systems. Northern Labrador has cold soils, which diminishes both chemical and biological activity within them. This has likely assisted the retention of anthropogenic



ents. The Inuit semi-subterranean dwellings that dot Labrador's coast ing locations because their collapsed roofs (when present) can seal the ath them, shielding the deposits from direct weathering. This could also help preserve the chemical residues produced by particular activities. Moreover, many landscapes in northern Labrador are remote and have not been used by people since their original abandonment, meaning recent land use has not obscured evidence of past human induced chemical enrichments.

The geoarchaeological methods employed in this research are minimally invasive. They can produce massive datasets while preserving the stability of tested sites by possibly reducing the amount of excavation needed to test their potential. Pedological research, in particular, can provide archaeologists with a unique dataset that can strengthen current understandings of past societies. Geochemical data from archaeological soils are potentially useful for interpreting structures of human habitation where artifactual and architectural evidence are absent, because soil deposits act as chemical records for the processes leading to their formation. Since this is the case, soil chemistry surveys are useful for locating sites, delimiting site boundaries, and interpreting spatially oriented activities (Wilson et al. 2008: 412).

Additionally, pre-excavation pH and Eh testing are useful for distinguishing areas having good or poor preservation potentials for organic materials. Such testing can help identify locations that potentially contain well-preserved faunal remains, which are necessary for interpreting subsistence, economy, and site seasonality. This type of testing is also useful for determining if a given depositional context is a viable alternative for storing large collections of faunal remains. If a soil deposit has characteristics beneficial

to the preservation of organics, faunal materials could be reburied after documentation and sampling as a means of long-term storage and preservation. Additionally, archaeologists can predict field conservation requirements such as the types and quantities of essential supplies using such reconnaissance testing, which is an important logistical concern when conducting archaeological research in remote locations such as northern Labrador. Post-excavation conservation can also benefit from this type of testing. If a site undergoes testing before excavation, archaeologists can predict the material types most likely to survive, their possible volume, and their condition. Accordingly, archaeologists and conservators can arrange treatments and storage before excavations begin (Cronyn 1990: 96). Identifying how pH and Eh influences the survivorship of anthropogenically enriched elements is equally important.

Moreover, the geochemical attributes of archaeological soils are potentially useful for interpreting social organization. Linderholm (2007) elaborates using P enrichment data from several sites in Sweden dating between the Bronze Age and the Late Iron Age (3500-1000 B.P.[1]). He argues that P enrichment in archaeological soils is related to population density, economic organization, the spatial organization of habitation areas, and trash disposal practices. Phosphorus is insoluble within soil systems and is cycled by plants, meaning enrichments caused by human activity should remain relatively stable over time. He hypothesizes that societies having different socioeconomic organizations such as hunter-gathers, pastoralists, and agriculturists produce different concentrations of P. He was able to demonstrate that short and long occupations produced low and high P enrichments respectively, likely owing to differing population densities that generated

[1] The dates in this thesis are reported as they appear in their original sources.

different amounts of organic wastes. House features also had relatively high P concentrations, suggesting that sedentary societies produce, and subsequently deposit, greater amounts of organic wastes (Linderholm 2007: 420, 429, 433).

Similarly, Harrison and Hancock (2005) demonstrate how the elemental characteristics of clays used in ceramics from an Early Iron Age (1200-1000 B.C.E.) site in Israel are useful for understanding socioeconomic differentiation among neighbouring communities. The authors identified six groups of ceramics with differing elemental compositions, reflecting differential, perhaps socially stratified, access to particular clay resources. This logic also applies to the chemical characteristics of archaeological soils. For example, do archaeological deposits containing spatially patterned concentrations of material culture indicative of particular socioeconomic status also have unique geochemical signatures?

Combining previous research addressing Inuit social organization with pedological data can provide unique insight into Inuit spatial and social phenomena such as economic organization, gendered labour and space, and ceremonial life. Grier and Savelle (1994) hypothesize that the patterned use of space in Inuit communities reflects socioeconomic organization. Whitridge (2002: 170-173) and Savelle and Wenzel (2003: 104-106) elaborate using Inupiat (Alaskan Inuit) *umialit* (boat owners) as an analogy. Boat owners had significant wealth and social power, being the primary organizers of communal hunting campaigns. They often accumulated surpluses of fuel, food, prestige goods, and choice building materials, distinguishing their social status and material lives from those of non-boat owners. Spaces associated with men's and woman's labour can also be delineated inside Inuit dwellings using distributions of gendered objects such as

uluit, or women's knives. Whitridge (2002: 166; 2004a: 45-47) observed that spaces such as sleeping platforms and lamp areas are dominated by refuse indicative of male and female activities respectively. Houses serving a ceremonial function, called *kariyit*, also have architectural and artifactual distinctions from typical dwellings. These places are also associated with refuse from male activities (Whitridge 2004b: 242). Combining this type of archaeological evidence with pedological evidence can help determine whether these reflections of social organization have corresponding chemical signatures in soils from particular spaces. For example, is there a correlation between the spatial distribution of gendered objects and soil geochemical signatures? A positive correlation could signify that gendered activities produced spatially distinct concentrations of both material culture and chemical signatures in soil deposits.

Although some archaeopedological investigations have been undertaken in arctic and subarctic contexts, the present research is the first conducted in northern Labrador. Regarding Newfoundland, similar research was conducted by Mathias (1998), who considered the effects of archaeological soil deposits on ferrous iron at a 17th century English colonial site in Ferryland. Previous archaeopedological research conducted in Thule contexts by McCartney (1979b) and Derry et al. (1998) are useful guides for the present research. McCartney's (1979b) research took place on Silimiut Island in northern Canada, which was occupied by Thule Inuit people around A.D. 1200. She examined how Thule semi-subterranean house construction and habitation affected soil chemistry and vegetation growth. McCartney (1979b: 496, 500-502) concluded that soils inside and around Thule houses have spatially defined element enrichments. Specifically, soils inside Thule houses became loaded with N and P because of accidental fertilization with

food remains, subsequently causing an increase in vegetation growth atop the enriched soils. Derry et al. (1998) studied soil chemistry at the Thule site of Arnaqquaksaat, on Igloolik Island in Nunavut, northern Canada. The authors speculate that the site was occupied for over 1000 years, first by Dorset people and later by Thule people. However, they focused on the impacts that Thule dwelling construction and habitation had on soils in the area. To determine the effects of these activities, influenced and non-influenced areas were identified by considering differences in vegetation cover over the region. Anthropogenically influenced areas had a continuous vegetation cover compared to the relatively low vegetative cover of adjacent polar semi-desert areas. The authors conclude that past anthropogenic influences decreased the pH and increased N, P, and Mg concentrations in the soils associated with the dwellings. Soils were also deeper in areas influenced by human activities. The authors explain that N, P, and Mg were also significantly enriched in areas influenced by birds and mammals, suggesting that caution must be exercised when interpreting chemical eutrophication on archaeological sites. That is, one must ensure that human, rather than animal, influences are being measured (Derry et al. 1998: 204, 207, 211).

My research adds to the approach discussed by these authors. Data were collected from four Inuit archaeological sites in northern Labrador. Specifically, soils from two dwellings at Iglosiatik Island, one at Nachvak Fiord, three at Komaktorvik Fiord, and one at Big Head were explored (Figure 1.1). The town of Nain, which is the most northerly community in Labrador, was the base of operations for this research. Iglosiatik Island is approximately 50 km south of Nain in outer Voiseys Bay. Investigations there focused on HbCh-1, an early Labrador Inuit winter habitation site occupied between the 15th and 17th

centuries. Nachvak Fiord, Komaktorvik Fiord, and Big Head are located in the Torngat Mountains National Park Reserve. These sites are between 300 and 340 km north of Nain. The winter habitation sites investigated in these areas are designated IgCx-3, IhCw-1, and IiCw-1 respectively. Nachvak Village, or IgCx-3, was occupied between A.D. 1450 and 1700. Komaktorvik 1, or IhCw-1, has Inuit components dating between the 15th and 19th centuries. Big Head 1, which has the Borden designation IiCw-1, was occupied by Inuit people between the 15th and 20th centuries.

This thesis is organized into seven chapters. The present chapter serves as an introduction, outlining research goals, project benefits, and data collection locations. Chapter two discusses the theoretical background of the research and reviews several similar projects. Field and laboratory methods are discussed in chapter three. Chapter four describes Inuit houses in general, my specific research locations, and the data collected from these locations. Statistical analyses of the data are discussed in chapter five. Chapter six considers the Inuit activities that could have caused any observed changes in soil chemistry. Lastly, chapter seven summarizes the project and provides suggestions for future research.

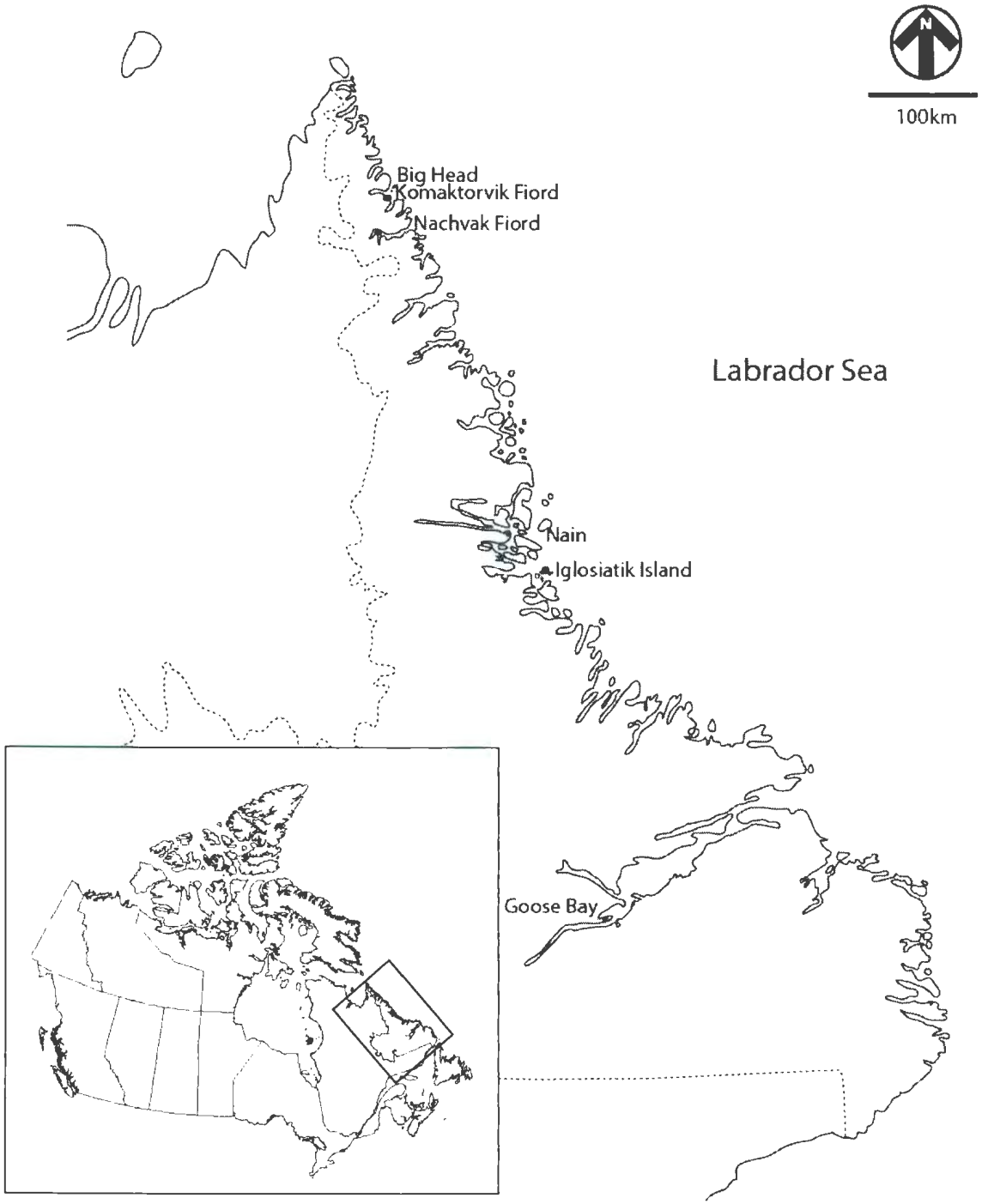


Figure 1.1: Map of Labrador Showing Research Locations (Adapted from the National Topographic Data System, Natural Resources Canada, 1999)

CHAPTER TWO

THE GEOCHEMICAL RECORD OF CULTURAL PRACTICE

If particular culturally defined activities produce unique chemical by-products that become incorporated into soil systems, and these activities are spatially organized, then these activities should be identifiable in soil systems as spatially patterned chemical enrichments. Fully conceptualizing this argument involves integrating the concepts of practice, dwelling taskscapes, and soil chemistry eutrophication. Additionally, a review of previous research addressing soil chemistry from various archaeological contexts will identify soil properties that can be altered because of human activities, both strengthening the argument that spatially oriented human behaviours cause patterned chemical enrichments in archaeological soils and serving as a comparative reference for the types of cultural practices that can alter soil chemistry.

Theoretical Framework

People typically behave particular ways in specific places. The concepts of practice, *habitus*, social memory, social expectations, structuration, and social monitoring are useful for understanding why people routinely partake in spatially particular activities. Additionally, the concepts of taskscapes/activity areas, soilscapes, and eutrophication are useful for understanding how these behaviours are identifiable in the archaeological record.

Ortner (1984: 127) states that practice is "neither a theory nor a method in itself, but rather... a symbol, in the name of which a variety of theories and methods are being developed". This variety of theories, however, all attempt to explain relationships between behaviour and social structure. For example, Dobres and Hoffman 1994,

Lightfoot et al. (1998), Owoc (2005), and Atalay and Hastorf (2006) have used practice based theories to consider how social structures are reproduced or transformed over time and space by people's informed, reflexive behaviours. Following Bourdieu (1990), social structures are systems of accepted relationships, or unconscious rules that prescribe and proscribe certain behaviours in certain social situations. Essentially, practice is behaviour that is informed by these structures. According to Bourdieu (1990: 53), "[t]he conditionings associated with a particular class of conditions of existence produce *habitus*, systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organize practices...". *Habitus* refers to perceptions and behaviours that are shared by a certain category, or class, of people. It is a product of social structures, collective social histories, memories, and early childhood socialization. These shared experiences contribute to how people perceive both social and physical contexts, and subsequently, how they behave in those contexts. According to Bourdieu (1972, 1990), this produces both conditioned and conditional behaviours, suggesting contextually specific behaviours are both socially expected (i.e. conditioned) and necessary for survival (i.e. conditional).

People learn *habitus* early in life, and the early stages of life are often associated with houses, suggesting that behaviours acceptable within houses are among the first, and subsequently the most entrenched, that are learned. Additionally, the spatial organization of dwelling activities is a product of collective social histories, meaning people's mutual experiences, and their memories of these experiences, influence their decisions of how to behave in particular dwelling spaces. People see their families (and other social units) enacting spatially particular practices on a daily basis, they hear stories of their ancestors

doing the same, and they remember these experiences. People remember that the same tasks were done in the same places last year, and the years before. Following Hodder and Cessford (2006), shared social memories, histories, and experiences typically compel people to enact practices that recreate past ones, suggesting that routine, dwelling oriented activities are characteristically performed in the same discrete places over time.

Also addressing routine behaviour, Giddens (1976: 75) describes practice as "the lived-through process of everyday conduct... or the stream of actual or contemplated causal interventions of [people] in the ongoing process of events in the world". In other words, people's daily lives consist of a continuous flow of activities that are guided by existing social systems and structures, interactions with other people, and physical contexts. Giddens (1984: 25) defines social systems as empirically observable behaviours that link people across time and space, while social structures are the rules (which are somewhat unconscious) that guide these behaviours. People use these rules, which exist virtually, or cognitively, to avoid negative social interactions while they navigate their way through daily life (Giddens 1984: 17). People's recursive behaviours reflect these social structures, as they are both the product and cause of such structures. Moreover, people have a substantial amount of knowledge regarding structural rules, making them capable of contextually appropriate behaviour, which in turn allows them to properly "... go on within the routines of social life" (Giddens 1984: 4).

Giddens (1984: 25) defines structuration as social practices ordered across time and space in virtue of the duality of structure. His concept of the duality of structure suggests that social structures are both the medium and outcome of behaviour. Similar to Bourdieu's (1990: 53) "structuring structures", the routinized aspects of behaviour are

both conditioned by existing social structures and recreated by individuals during their daily activities. People are also naturally reflexive, meaning their purposive, everyday actions are guided by social monitoring. That is, people monitor their own actions, the actions of other people, and they expect other people to monitor them as well (Giddens 1984: 5). These social expectations both enable and constrain (or prescribe and proscribe) behaviour. Social expectations suggest that activities should be practiced in appropriate social and physical contexts such as certain places on the landscape or particular dwelling spaces. For example, the collective, recursive act of disposing of food remains in the same place creates a social expectation for the disposal of those wastes in that manner. Moreover, the social monitoring that occurs within houses generates expectations for behaviours and activities acceptable in that context (like removing wastes), which influences decisions of how to use spaces within them. Essentially, people know, tacitly, how to behave in particular contexts because of social expectations and social monitoring.

Recursive, structure influenced behaviours are visible in the archaeological record as architectural styles, tool morphologies, and spatially organized activity areas (Morris 2004). Borrowing from Ingold (1993), dwellings consist of several taskscapes, or activity areas, collapsed into various, often patterned locations on the landscape. Taskscapes are physical, social, and mental constructs. They represent sets of activities and ideas that are socially attached to particular places. Binford (1983: 147, 148) defines activity areas as places, facilities, or surfaces where people partook in particular behaviours such as eating, sleeping, tool making, and ritual. An activity, then, is a set of related behaviours, or tasks, done in uninterrupted succession to facilitate some end. Cooking, for example, involves several interrelated tasks such as preparing and tending the hearth, preparing the food,

and monitoring the actual cooking process. Pearson and Richards (1994: 3) also suggest that space physically constrains behaviour, meaning certain spaces lend themselves to the enactment of particular activities. For example, activities such as butchering a caribou and working the procured hide require certain types of space (Binford: 1983; Dawson et al. 2007).

Binford (1983: 144) argues that activity areas can be identified using spatial distributions of architectural features, artifacts, faunal materials, and other types of features. According to Oswald (1984: 299) and Allison (1999: 6, 7), particular types of activities such as cooking occur frequently, at regular intervals, in fixed locations, meaning spatially fixed activity areas are often associated with accumulations of debris indicative of the behaviours performed in them. Patterned accumulations of material culture, then, reflect the recursive aspects of behaviour, which in turn reflect the social structures that guided such behaviour (Pauketat and Alt 2005: 218). These material representations of routine behaviour are useful for tracing spacio-temporal change and persistence in the structures guiding them (Lightfoot et al. 1998: 200, 215; Allison 1999: 5-7; Hoffman 1999: 150). Following this, the reproduction of structures guiding the enactment of spatially defined practices might appear in the archaeological record as spatially uniform soil signatures over both time and space. Conversely, varying soil anomalies over time and space could indicate changes in social expectations for spatially oriented behaviour.

Quoting Holliday (2004: 1), "[s]oils are a part of the [ecological] stage on which humans have evolved". They are also a part of the social stage on which innumerable cultural practices were performed. Soil systems reflect relationships between natural and

cultural processes, as well as the passage of time. Soils also serve as a repository for material culture and other traces of human behaviour such as chemical anomalies. Soil is typically defined as a loose mass of physically and chemically weathered geological materials and organic matter (Harpstead and Hole 1980: 4). Gerrard (2000: 1) defines soil as "... a natural body composed of minerals, organic compounds, living organisms, air, and water in interactive combinations produced by physical, chemical, and biological processes". Sediments are defined as particulate matter transported from one area and deposited in another by wind, water, gravity, or some other process (Stein 2001: 6).

Soil systems are typically composed of both soils and sediments. Limbrey (1975: 47-48) and Gerrard (2001: 12-18) explain that minerals, organisms, non-living organic materials, the soil solution, and the soil atmosphere are the primary constituents of soil systems. The major ingredients in any given soil systems are minerals, which comprise approximately 45% of its volume. The mineral component of a given soil system is derived from local geology. This component influences characteristics such as structure, texture, colour, and the operation of several physical and chemical processes. The living components of soils include plant roots, animals, and microorganisms, which contribute to physical and chemical processes within the system. Soil systems typically contain approximately 5% organic material by volume. The main organic component of soil is humus, which is composed of plant and animal materials in varying stages of decomposition. Oxygen in soil systems is held between clay, silt, and sand particles, comprising approximately 25% of the soil's volume. The amount of oxygen in a soil, and the rate at which it is replenished, influences its ability to produce particular chemical reactions. Water, which comprises 25% of the soil's volume, is hygroscopic, meaning its

high surface tension causes it to attach to the surfaces of particles as a film. Water is also generally referred to as the universal catalyst, because it is necessary for the innumerable chemical reactions that occur in soil systems.

The soil system, or pedoshpere, interacts with other systems, namely the atmosphere, biosphere, lithosphere, and hydrosphere (Gerrard 2001: 3). For instance, and perhaps most importantly, humans, as a part of the biosphere, can influence soil systems through inputs of chemical residues derived from a rather large inventory of culturally defined practices. Soil systems are three-dimensional records of both the natural and cultural processes that contributed to their formation. As discussed above, they have physical aspects, but when humans change their composition through the performance of particular tasks above them, they become records of practice, knowledge, and memory. They become soilscapes. Wells (2006: 125) defines cultural soilscape as "...a given area of the Earth's surface that is the result of spatially and temporally variable geomorphic, pedogenic, and cultural processes... reveal[ing] the consequences of the complex and multilayered dialectic between human behaviour and soil bodies over long periods". Soilscapes are more than simply space. When people consistently perform particular tasks in a spatially defined locations above soil deposits, the deposits become places, or soilscapes, which are imbued with memory and changed by cultural ideas regarding the use of associated places (Pauketat and Alt 2005: 217).

Soils associated with Inuit houses can act as chemical archives for spatially oriented activities. Following Binford's (1983), Oswald's (1984) and Allison's (1999) approach to activity areas, when specific activities are enacted in the same places over time, their liquid and/or particulate by-products can become spatially concentrated in the

associated soil system, meaning spatially patterned chemical anomalies in archaeological soils likely represent routine, spatially organized practices. Of course, these chemical by-products are comprised of elements, which become rapidly fixed to the mineral surfaces of sediment grains. They are somewhat stable in soil systems, being absorbed into clays or organic materials as complex ions, or forming insoluble oxides, sulphides, or carbonates. These processes help retain anthropogenic elemental inputs by reducing their mobility within the soil system (Entwistle et al. 2000: 296, 297; Wells 2004: 71). Additionally, cold soils, particularly those containing permafrost, are poorly drained, which should reduce leaching of human induced elemental inputs (Knudsen et al. 2004: 449). As discussed above, different types of activities are typically performed in different locations, which can cause spatial variation in soil chemical characteristics (Middleton and Price 1996). In pedology, soils distinguishable from their surroundings based on chemical enrichment from outside sources, or showing extreme spatial variability, are referred to as eutrophied. Accordingly, soils having chemical enrichments derived from human activities are anthropogenically eutrophied.

Spatial variations in soil characteristics are useful for distinguishing types of settlement features such as dwellings, hearths, paths, livestock housing, and activity areas (Entwistle et al. 2000; 2007). Middleton and Price (1996: 677) state that activities such as cooking produce large quantities of residues and debris that become incorporated into associated soil systems. Additionally, Cook et al. (2005: 629) state that houses with soil floors, like Labrador Inuit houses, contain massive amounts of organic refuse and micro-debitage such as tool manufacturing by-products. These by-products can cause spatially patterned changes in particular soil characteristics, which are discussed in detail below.

Anthropogenic Eutrophication in Archaeological Soilscapes

Since Arrhenius's seminal 1931 research regarding P enrichment on archaeological sites in Sweden, several researchers (e.g. Linderholm and Lundberg (1994), Barba et al. (1996), and Middleton (2004)) have demonstrated the benefits of using soil chemical data to understand archaeological sites. Additionally, Wells et al. (2000) demonstrate that combining architectural and artifactual evidence with the chemical properties of soils is useful for identifying and understanding land use patterns such as the spatial organization of domestic activities. Conversely, Terry et al. (2000, 2004) demonstrate that spatially patterned element concentrations in archaeological soils are useful for defining spatially oriented practices that are not easily identified by artifactual evidence alone.

As outlined above, McCartney (1979b) and Derry et al. (1998) conducted influential archaeopedological studies on Thule sites in northern Canada. Similarly, Griffith (1980, 1981) considered the chemical characteristics of soils from a Huron site in Ontario, Canada. Specifically, his research distinguished soils on the Benson site, which was occupied during the 17th century, from adjacent natural areas using concentrations of Mg, P, Ca, K, Na, and pH. One hundred and fifty soil samples were collected from the site using a 1 by 1 m sampling grid and compared to three off-site samples. Comparisons of mean concentrations between on-site and control samples indicated that Mg, Ca, K, and P were significantly higher in the archaeological soils. Discriminant analysis was used to chemically define areas such as longhouse interiors, middens, storage pits, hearths, post moulds, and pathways. The results indicate that middens have the most chemically distinct soils, having characteristically high values for Mg, P, and pH. Soils

from house, hearth, pit, post mould, and pathway features are somewhat similar, but they also have minor distinctions. In order of decreasing magnitude, the variables useful for distinguishing spaces on the Benson site are Mg, P, Ca, K, and pH. Griffith (1980, 1981) also comments on the potential anthropogenic sources of these enrichments. He states that wood ash and charcoal contain large quantities of Mg, explaining its high concentrations in hearth areas. However, Mg is also a by-product of the decomposition of animal bone, suggesting it should also have high concentration in middens. The elements P and Ca have very high concentrations in excrement, animal tissues and fluids, and other types of organic wastes, explaining their enrichment in trash disposal and cooking areas. Soils that were burnt or contain large amounts of incorporated wood ash can have increased concentrations of K.

Additionally, Moore and Denton (1988) identified the chemical characteristics of archaeological soils in the Caniapiscau Region of northern Quebec. Specifically, they determined pH, P, Ca, Mg, and K concentrations at a First Nations site (1400 - 400 B.P.) and various non-habitation, or control areas. One hundred samples from the archaeological site were collected using a 10 by 10 cm sampling grid. Elemental concentrations were determined using NH_4F/HCL extraction and pH was determined using an electronic meter. Interestingly, pH, P, Ca, and Mg had increased concentrations over control means along a single vector, which was interpreted as an axial hearth feature inside a long-house. The authors suggest that these increases likely originated from anthropogenic inputs of charcoal, bone, and other types of organic matter both in and around the hearth.

On the west coast, Middleton and Price (1996) investigated the Keatley Creek site in British Columbia to determine if particular human activities are chemically distinguishable in soils. The site was occupied continuously across three cultural horizons (Shuswap 2400-4000 B.P.; Plateau 1200-2400 B.P.; Early Kamloops 1200 B.P.) and has approximately 115 semi-subterranean dwellings. Soil samples were collected from the floor layers of one house. Inductively coupled plasma-atomic emission spectroscopy was used to identify concentrations of Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, Sc, Ti, and Zn in both on-site and off-site samples. Compared to the off-site samples, several patterns of elemental enrichment were apparent within the house floor. The center of the floor had enriched concentrations of K, Mn, P, and Zn, which could indicate a cooking area. The authors suggest that wood ash can contribute K and P to soils, while organic wastes can contribute Ca and P. The southwestern half of the house had increases in Ca and Sr. Enrichments in Sr in archaeological soils could indicate roofed areas. The southeast floor perimeter had increased levels of Al, Fe, and Mg, perhaps indicating an accumulation of refuse from producing stone tools.

Several archaeopedological studies have also been conducted in the United States. For example, Chaya (1996) investigated a site in the Aleutian Islands, Alaska, identifying that refuse disposal practices can cause P enrichment in soils. Schlezinger and Howes (2000) also examined P enrichment at the Carns site in Massachusetts, a First Nations site that was occupied around 1400 B.P. Concentrations of P were determined using a H_2SO_4 extract and statistically significant differences between archaeological and control soils were identified using student's t-tests. The results of their analysis suggest that P enrichment is a useful indicator for vertical cultural horizons.

In addition, Sullivan and Kealhofer (2004) identified the geochemistry of soils at a 17th century colonial site in Virginia. Specifically, they considered P and Ca enrichment at the Rich Neck site. Thirty-three soil samples were collected from various features such as the kitchen of a house, plough zones, spaces between houses, and gardens. The authors observed that the control samples had much lower concentrations of P and Ca than on-site samples, suggesting that human activities caused increases in these elements. Substantial P elevations were associated with kitchen areas and spaces between structures, which could indicate trash disposal habits. High P concentrations in plough zones could also arise from the use of animal manure as fertilizer. Concentrations of Ca were highest around the house's walls and the kitchen area. Calcium carbonate is a major constituent of oyster shells and wood ash, suggesting that enriched concentrations of Ca around kitchen walls might represent the bulk processing of dietary shellfish. The high concentration of Ca in the kitchen could represent a hearth area.

Using an ethnoarchaeological approach, Knudsen et al. (2004) considered the geochemical fingerprints of fishing activities at two modern Cupiit fishing camps in Alaska. To determine the effects of fishing activities on soils, samples from areas not used in the fishing process were used as controls. The authors measured the elemental composition of soils from gutting/cutting, soaking, drying, and smoking areas using ICP-AES. They discovered that fish-cleaning areas have increased concentrations of Ca, K, Na, and Mg. Soil samples extracted from beneath fish drying racks have highly elevated concentrations of Mn, P, and Sr. Drying areas also have slightly elevated concentrations of Ba, Ca, Fe, K, Mg, and Na. The authors hypothesize that fish smoking areas would have elemental loadings similar to an archaeological hearth, showing increases in K, Mg,

and P. The smoking areas only have evidence of increased Mg, because smoking fires were contained in steel drums. One camp was used seasonally for thirty years and the other for only one. Interestingly, soils from both fish camps have similar chemical characteristics, vouching for the stability of cultural elemental loadings in cold soil systems over time.

Extensive archaeopedological research has been conducted on Mayan sites in Central America. Several projects have been conducted at Piedras Negras in Guatemala, which is a Classic Mayan (A.D. 250 - 850) city consisting of residential dwellings, civic and ceremonial buildings, sweat baths, and cemeteries. Wells et al.'s (2000) research at Piedras Negras aimed to determine whether spatially patterned concentrations of P, Fe, Hg, Mn, and Cu are useful for identifying activity areas prior to excavation. Concentrations of P were determined using Mehlich II weak acid extraction and the heavy metals were quantified using DTPA extraction. The authors collected over 100 soil samples from the residential area using a 1 by 1 m sampling grid. They discovered that middens have very high increases in P, suggesting that waste disposal practices are identifiable though varying concentrations of this element. Another midden contained high concentrations of Mn, Cu and Hg, but had low concentrations of P, suggesting it was not used for dumping subsistence-related garbage. Perhaps this area was used for dumping refuse related to craft production. Additionally, a domestic patio area had high concentrations of both upper and lower class ceramics and musical instruments, suggesting it was a trash disposal area used by royal servants. This midden also had high concentrations of Hg. Lastly, high concentrations of the elements Fe, Hg, Mn, and Cu

were found at the base of a residential dwelling. The authors suggest that these enrichments derived from the paints that once adorned the house's walls.

Parnell et al.'s (2001) research at Piedras Negras focused on delimiting midden areas using increased concentrations of P (quantified by Mehlich II extraction). Over 400 soil samples were collected from three groups of domestic dwellings. Concentrations of P were increased in all the dwellings. High concentrations of P were also found in association with a steep slope, suggesting that organic refuse was simply dumped over its side. Test pits near the one of the biggest structures on the site yielded large densities of faunal remains, ceramics, charcoal, and relatively high P concentrations, suggesting the area was used as a kitchen midden. Several areas with high densities of faunal remains and high concentrations of P suggest the presence of numerous kitchen middens. Parnell et al.'s 2002 research at Piedras Negras moved beyond identifying middens to identifying activity areas. They considered how spatial variation in concentrations of P, Cu, Fe, Hg, Mn, Cd, Pb, and Zn are useful for understanding the organization of domestic behaviours. Concentrations of P were determined by Mehlich II extraction and trace metals were identified using DTPA extraction. Ninety-one samples were taken from the occupation floor of a multi-roomed structure during its excavation. The authors identified an interesting pattern of P concentrations. The north room and its adjoining passages had some of the highest P concentrations. Using both artifactual and chemical evidence, this room was interpreted as a food preparation area. Additionally, elevated P around bench areas in this room suggests they were food consumption areas. The authors also observed a distinct pattern moving from room to room eventually into the patio area, which had the highest concentration of P. This represents sweeping/cleaning, or refuse disposal

activities. High concentrations of Cd, Cu, Ba, and Mn were associated with refuse produced by subsistence related activities and various types of craft production. The elements Cu and Mn had high, isolated concentrations in two areas, suggesting they were pigment/mineral grinding areas. As with patterns for the other elements, patterns in Fe, Hg, and Pb appear to reflect craft production and refuse disposal activities.

Similar to the research undertaken at Piedras Negras, Terry et al. (2004) identified the chemical imprints of daily activities at two sites in Aguateca, Guatemala. Specifically, they investigated the chemical compositions of soils from an ethnographic site and a nearby Classic Mayan site. Both sites were rapidly abandoned. The ethnographic site was a guardhouse that was occupied from 1980 to 1998. Samples were taken from the kitchen, eating area, bunkroom, covered porch, trash disposal area, and garden. The highest P concentrations were identified in both the kitchen and midden areas. High concentrations of Fe in discrete locations were interpreted as machete sharpening areas. Investigations of the archaeological site revealed spatially patterned P concentrations interpreted as the results of food preparation/consumption and waste disposal. A high concentration of Fe was associated with a pyrite processing area. High Cu concentrations in isolated spaces could have derived from the use of Cu ores as pigments. Archaeologically identified midden areas also had increases in Cu, Fe, Mn, and Zn. The authors conclude that soil chemical data from ethnographic sites are useful for understanding the types of activities that can cause element increases, meaning they are useful comparative resources for data from archaeological sites.

As Terry et al. (2004) have identified, perhaps the best contexts to investigate anthropogenic eutrophication are those that have been rapidly abandoned, sealed, and not

re-occupied. Cook et al. (2005) have identified such deposits at a Late Classic Mayan (A.D. 600-800) site in Cancuen, Guatemala. To distinguish human influenced soils, the authors compared samples from dwelling floors and off-site areas. Specifically, they employed ICP-MS to identify the rare earth element (Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) content of 75 soil samples. The rare earth elements are insoluble in water and immobile in soils, meaning human inputs of these elements should be well preserved. Interestingly, the authors discovered that all of the rare earth elements were increased in the soil floors between 10% and 20%. Accumulations of teeth, hair, fingernails, and skin from general occupation and perhaps personal grooming practices could cause increases in these rare earth elements. They also consider non-anthropogenic sources for rare earth element enrichment such as marine plants, shells, and animal manure. Conceivably, these materials could also find their way into soil systems via anthropogenic transportation.

Considering the Late/Terminal Classic Mayan Period (A.D. 600-1000), Wells (2004) studied the chemical composition of archaeological soils at a site called El Coyote in northwestern Honduras. Inductively coupled plasma-atomic emission spectroscopy was used to measure the elemental characteristics (i.e. Al, Ba, Ca, Fe, K, Mg, Na, P, Sr, Zn, Mn, and Ti) of soils to understand how residues from particular activities are deposited and preserved. Five hundred and thirty soil samples were extracted from the main plaza surface, a ball court surface, middens, and patio surfaces. These samples were compared to 13 off-site samples. Increases in P were identified throughout the plaza, though the highest concentrations were found in a large midden area. Different types of middens were also distinguishable based on their chemical compositions. Middens composed of

refuse from lithic tool production had increases in Fe, Ti, Al, and K. Subsistence related middens had high concentrations of ceramics and wood ash that correlated highly with enriched concentrations of P and K. Areas with large concentrations of faunal remains correlated highly with increases of Na and Ca. Patterns of P enrichment and high densities of food processing tools around some of the buildings suggest they were used for activities related to food preparation and consumption. However, other buildings had very low concentrations of P, suggesting they were used for activities that did not produce organic wastes. Phosphorus is also significantly increased in patio areas, reflecting their domestic function. The ball court, however, had very low concentrations of P in the playing area. Interestingly, the end zones had higher concentrations of P, strengthening the interpretation of these areas as stages for ritual feasts. Considering these results, spatial patterns in Al, Ba, Ca, Fe, K, Mg, Na, P, Sr, Zn, Mn, and Ti concentrations should be useful for understanding the spatial complexity of task organization across entire sites.

Several projects addressing human influences on soils have also been conducted in the United Kingdom. Entwistle and Abrahams (1997), for instance, considered soils from numerous sites across Scotland. They identified P, Sr, Pb, Cu, Zn, Ca, and Mg as potentially useful for understanding temporal changes in land use history. However, they warn that recent land use near and on archaeological sites can obscure evidence of historic and prehistoric anthropogenic eutrophication. Additionally, at the Skara Brae site (3100-2500 B.C.) in Orkney, Scotland, Simpson et al. (2006) determined that the disposal of wastes such as fuel residues increased the P content of the soil system.

Davidson et al. (2006) also considered human impacts on soils in Scotland. Their research took place in the town of Nairn, which is a small agricultural community

inhabited since the 12th century. Soils both in and around this community are much deeper and more fertile than soils in neighbouring areas. The authors hypothesize that the soils are plaggan soils that formed because of large inputs of human and animal excrement, turf, and other types of inorganic and organic refuse. Plaggan soils are deep and have P, Ca, Mg, Zn, and Mn enrichment. Overpopulation of Nairn during the 18th century generated massive amounts of waste. By 1756, trash was overflowing into the street, so legislation was enacted prohibiting trash disposal within 3 m of the street. This displaced waste disposal practices away from the town. Interestingly, this change in land management is evident in soil depth and P enrichment surveys. The site has extreme variability in soil depth and P concentrations in small, discrete spaces, representing the management of individual dump heaps before the enactment of the legislation. Soils near the 18th century town boundary are also very deep and have high P concentrations, suggesting that areas just outside the town boundary were used for communal dumping after 1756.

Entwistle et al. (2000, 2007) have contributed greatly to archaeopedological research in Scotland. In particular, they identified the spatial and temporal variation of soil characteristics in the Hebrides region of Scotland using ICP-MS and ICP-AES. These projects elucidate the benefits of using soil geochemistry for site prospection. Entwistle et al. (2000) collected 60 soil samples from the site of Greaulin, which was mainly occupied during the 18th and 19th centuries. The site consists of 13 dwellings and a large piece of farmland. Off-site samples were also collected to identify increases in elements on the site. Elevated concentrations of P, K, Rb, and Th are associated with dwelling floors, which likely originated from the deposition of by-products associated with household

tasks such as food preparation and storage. The elements K and Rb are also associated with the hearth features, suggesting that inputs of wood ash and charcoal caused their enhancement. Enrichment in the element Cs could arise from organic inputs such as food waste. The element Mg is increased in hearth areas, perhaps owing to accumulations of ash and charcoal. The elements Ca and Sr are associated with cultivated areas and might represent the use of marine animal shells, bone refuse, and fish remains as fertilizers.

More recently, Wilson et al. (2008) studied the geochemical characteristics of archaeological soils from six farm sites across the U.K. The sites were abandoned between the late 19th and mid 20th centuries. Using ICP-MS and XRF, the authors identified the geochemical characteristics of 832 archaeological samples and 145 control samples. Samples were collected from features visible on the ground surface such as hearths, house floors, kitchen floors, middens, gardens, and adjacent fields using a soil corer. The authors employed ANOVA and discriminant analysis to delineate discrepancies in element concentrations between the sampling areas. They identified elements increased on the site in general and elements having distinct increases in functional areas. Increases in Ti, Ni, and Fe, for example, occurred in all of the archaeological sampling contexts, suggesting they are indicative of general occupation rather than specific activities. The elements Ca, Sr, Zn, P, and Pb are elevated in hearths, dwelling floors, and middens, likely deriving from food preparation, consumption, and disposal. The elements Ba, Ca, P, Pb, Sr, Mn, and Zn tend to have varying spatial concentrations, suggesting they were produced by the performance of particular spatially oriented activities.

Summary

Dobres and Robb (2005) argue that linking theories of practice with material evidence from the archaeological record requires a methodology, which they define as a way of both thinking about and measuring data, or a kit of analytical tools specifically developed to answer particular types of research questions. Lesure (2005) adds that effectively linking practice theory with archaeological evidence necessitates a consideration of how human behaviours are expressed on an analytical level. Essentially, one must identify relevant analytical resources for answering research questions developed from practice theory. Here, this prescription is achieved by considering patterned chemical alterations in soils as material evidence for patterned sociocultural practices. I combine methodologies developed in analytical geochemistry and pedology with the concepts of practice, dwelling taskscapes, and soil chemistry eutrophication to understand the spatial organization of past Inuit behaviour. This effectively links a rigorous, empirical set of analytical methods with robust behavioural and pedological theories to understand the reproduction of Inuit ideas regarding the use of space.

Archaeological considerations of practice typically concern identifying how social reproduction and transformation are reflected through materiality. The archaeological record is comprised of empirical evidence, or materials indicative of social activities (e.g. artifacts, features, and chemical signatures). The concepts of practice, *habitus*, social memory, social expectations, structuration, social monitoring, and taskscapes/activity areas can be used to understand how the spatial organization of recursive behaviours are generated and materially expressed (Dobres and Hoffman 1994). Generally, the ordering of daily life is visible in the spatial organization of the material remains of routine

activities. Space is structured through these routines, which produce patterned accumulations of material culture and perhaps even chemical residues. The present research considers the chemical by-products of recursive household practices as material evidence for the reproduction of Inuit ideas concerning the use of dwelling space.

The projects described in the second half of this chapter are diverse, indicating that many archaeological contexts should contain evidence of anthropogenically altered soil chemistry. Considering this, the alkali metals Na, K, Rb, and Cs, the alkaline earth metals Mg, Ca, Sr, and Ba, the metals Al, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Ga, and Hg, the non-metal P, the rare earth elements Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu, and pH, which are identified by several other researchers as characteristics that can be altered by human activities, could also be elevated within soils associated with Labrador Inuit dwellings and middens. Both ICP-MS and XRF have been successfully employed by several researchers such as Cook et al. (2005), Entwistle et al. (2007), and Wilson et al. (2008), suggesting they will also yield valid results in the present research. The methodologies used to collect soil samples and quantify their chemical characteristics are described in the next chapter.

CHAPTER THREE

FIELD AND LABORATORY METHODS

Renfrew (1976) asserts that geology has always played a major role in archaeological theory and method. Hassan (1979) explains this further, stating that geoarchaeology applies theories and methods developed in the earth sciences, including geology and pedology, to archaeological research questions. More recently, Holliday (2004) elaborates on the influence that archaeological soil studies, or archaeopedology, had on the development of geoarchaeology as a whole. Soils are the medium in which most archaeology is performed, and they have always been important for interpreting site formation processes and temporality. Interestingly, some of the oldest applications of geological/pedological theory and method in archaeology are the use of soil chemistry for assessing human impacts on landscapes (e.g. Arrhenius 1931).

As discussed in the previous chapter, I combine methodologies developed in analytical geochemistry and pedology with the concepts of practice, dwelling taskscapes, and soil chemical eutrophication to understand the spatial organization of the activities that took place inside Inuit winter houses. The methods described in this chapter are categorized into field and laboratory techniques. The field techniques concern sample collection, including mapping, stratagraphic profiling, and soil sampling. Laboratory methods serve to both describe the soils and measure their chemical properties. The laboratory methods employed are texture, colour, pH, Eh, TDS, XRF, and ICP-MS.

Mapping and Profiling

The first stage of fieldwork for this project was to accurately record the spatial dimensions of the research sites. Because of time and equipment issues, only the Iglosiatik and Komaktorvik sites were mapped. A Nikon DTM 350 total station was used to establish a hypothetical x-y-z grid system (northing, easting, and elevation) over the sites. At each site, a benchmark (datum) was placed in an area having a higher elevation than the site, making the entire site visible from one location and reducing the need for secondary benchmarks. The ground in these chosen areas was also relatively flat and solid, helping avoid instrument levelling errors. Datum spikes were hammered into rock outcrops, making them relatively permanent. At Iglosiatik and Komaktorvik, semi-subterranean houses were mapped using sets of points outlining particular features such as exterior wall perimeters, the tops of wall berms, and the edges of sleeping platforms. Topography was recorded using north-south point transects across the sites. Maps were produced by plotting the obtained coordinates on standard graph paper. The maps, which were quite large, were digitally rendered and rescaled using Adobe Illustrator. Maps for the Nachvak and Big Head sites are adapted from Kaplan (1983).

Soil horizon profiling after excavation is also an important aspect of archaeological mapping. Here, horizon profiles are used to identify the soil's taxonomic designation, which will aid the identification of suitable control sampling areas. The profiles were produced using the line-level method. The Canadian Soil Classification System (CCWG 1998) was used to classify the soil deposits. This system organizes soil deposits into orders and suborders based on the physicochemical properties of their horizons. Mineral horizons are designated with the prefixes A, B, and C, while organic

horizons have the prefixes O, L, F, and H. An A horizon, for example, is a mineral horizon that forms near the surface in an eluviation zone. Surface deposits mainly consisting of live or decomposing vegetative matter are labelled O, and those consisting mainly of rock are labelled R. Horizons are further subdivided using lower case suffixes. The lowercase letter h, for example, signifies a horizon with a large accumulation of organic matter.

Soil Sampling

Parallel with Vizcaino and Canabate (1999), Wells et al. (2000), and Parnell et al. (2002), soil samples from the Nachvak site were collected from occupation layers during the excavation of a dwelling feature. Soil samples from the Iglosiatik, Komaktorvik, and Big Head sites were collected using a hand-operated soil corer, which is commonly used for archaeological soil sampling (see Entwistle and Abrahams 1997 and Wilson et al. 2008). The barrel of the stainless steel corer used here is 46 cm long with a diameter of 1.3 cm. The top 5 to 10 cm of each soil column was discarded to avoid testing the highly chemically active upper layer of the solum. Samples were cored from dwelling features recognizable on the surface, which were dwelling floors, sleeping platforms, lamp areas, tunnels, and house walls. Areas adjacent to tunnel mouths were cored along single transects at 50 cm intervals to identify middens. Inuit middens in northern Labrador typically have dark, organic soils with a greasy texture and large amounts of decayed bone and charcoal (James Woollett, Pers. Comm.). Several samples were collected from each identifiable dwelling feature and were analyzed as representative composites. All of the soil samples were placed into polyethylene zip-lock bags and stored in a cool, dark

place to avoid unwanted chemical reactions, and thus sample contamination (Paetz and Wilke 2005: 28).

Following Linderholm and Lundberg (1994), Cook at al. (2006), and Wilson et al. (2008), control samples were collected to represent non-anthropogenically influenced soils. Control samples serve as a natural baseline useful for distinguishing spatial geochemical alterations that may be attributable to human activities. Middleton and Price (1996: 675) suggest collecting control samples from approximately 250 m away from the nearest dwelling or feature on an archaeological site. Control samples should only be taken from deposits devoid of cultural materials. Control sampling locations should also have similar elevations, slopes, geology, pedology, faunal influences, and vegetation cover as the archaeological sites (Stein 2001: 21). In the present research, these criteria were adhered to as closely as possible when choosing control areas at each site.

Texture and Colour

Describing the texture and colour of each sample is an essential preliminary step in pedological laboratory research. These qualitative assessments distinguish soil samples nominally. Soil texture refers to the fineness or coarseness of a given sample. The three components of soil that determine its texture are sand, silt, and clay, which are defined according to their particle size. Sand particles range between 2.0 and 0.02 mm, silt ranges between 0.02 and 0.002 mm, and clay particles are smaller than 0.002 mm. The amount of each component present in a soil determines its texture. For example, a soil having equal amounts of each component is defined as a clay loam. Soil texture influences processes within the system such as eluviation and chemical exchange (Harpstead and Hole 1980: 14; Gerrard 2000: 22-24). Methods for assessing texture are well documented.

Here, the procedure described by Banning (2000: 239) was used to identify the texture of each soil sample (Figure 3.1).

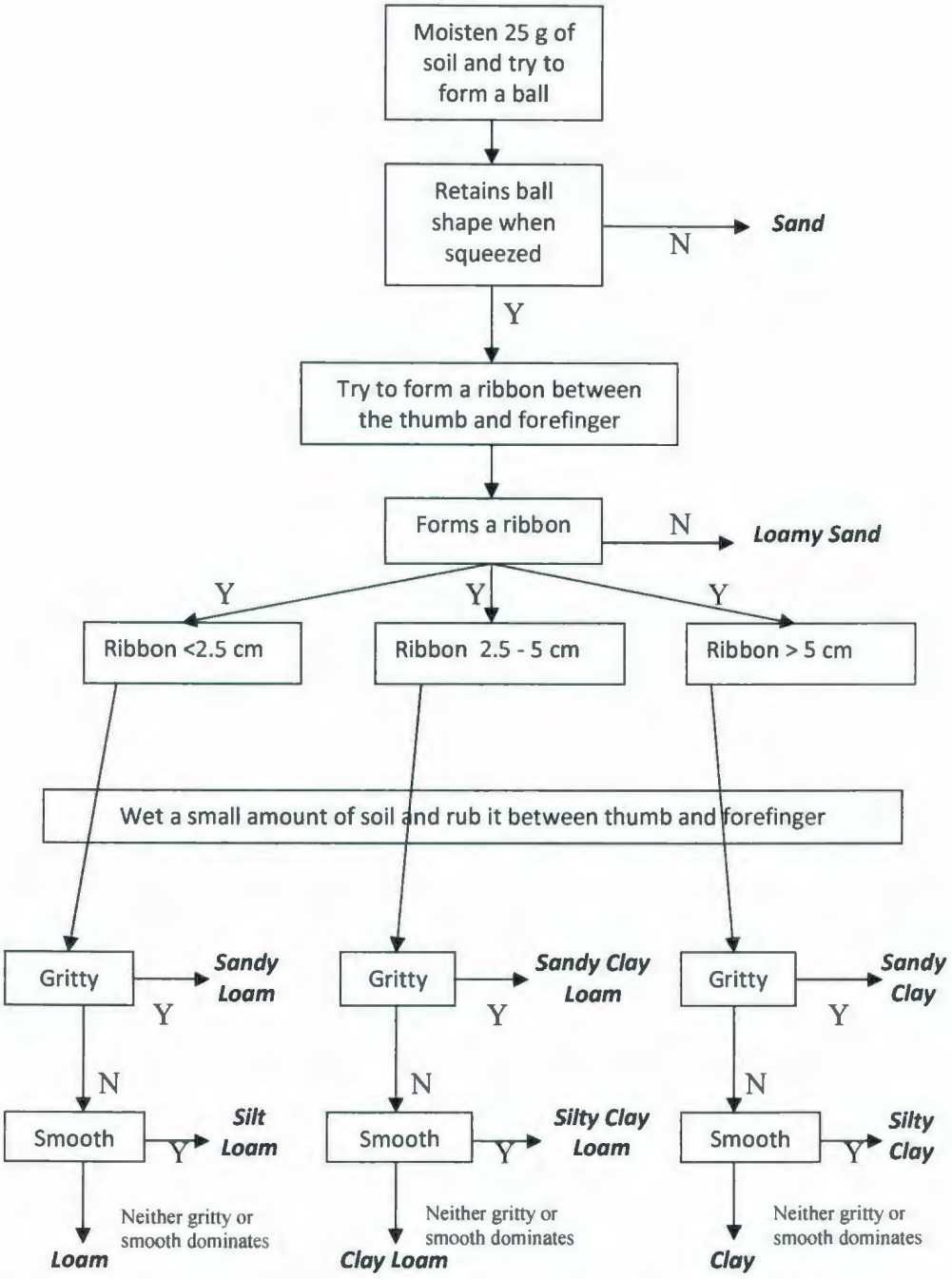


Figure 3.1: Soil Texture Classification (Adapted from Banning 2000)

The colour of each soil sample was identified using the Munsell (1975) soil colour system. This system describes the three main attributes of perceived colour, which are hue, value, and chroma. Hue refers to a soil's colour in relation to the colours red, yellow, green, blue, and purple, which is measured on a scale ranging from 0 to 10. Hue is recorded as a number, indicating its intensity, and a capital letter, representing its colour (e.g. 10YR). A colour's value indicates its lightness/brightness. Value ranges from 0 to 10. Zero represents pure black and 10 represents pure white, so lower values are darker and higher ones are lighter. Value is recorded a space after hue and is separated from chroma with a slash (e.g. 10YR 2/). Chroma is the strength of the colour, or its relative degree of departure from neutral grey, and is reported as a number ranging between 0 and 20, where 0 represents neutral grey and increasing numbers represent darker shades of grey (e.g. 10YR 2/2). Soil colours were determined by comparing wet soil samples to Munsell (1979) reference charts.

Chemical Reactivity

The chemical reactivity of a soil system refers to its ability to generate chemical reactions. For example, pH, Eh, and TDS/EC are measures of a soil's chemical reactivity. The activity of hydrogen ions (H^+) in a given liquid is called pH, or acidity/alkalinity (Gerrard 2000: 43; Wilke 2005: 69). A solution's active acidity, which is a measure of the intensity of acidity/alkalinity, not the amount of H^+ present, is the most common type of pH measurement used in soil sciences. Soils contain water, and water contains free hydrogen (H^+) and hydroxyl ions (OH^-). These ions have equal concentrations in neutral (pH 7) solutions such as distilled water, in which the concentration of H^+ ions is $1x10^{-7}$ g/l, or one H^+ ion for every $1x10^7$ water molecules. Since this is a very small number, pH

values are reported using a negative logarithmic scale [$-Log_{10}(H^+)$], which is the reciprocal of the H^+ concentration in g/l. Increases in H^+ or OH^- in a soil deposit lowers and raises its pH value respectively (Head:1980: 224). For instance, soil systems in areas with high rainfall and low evaporation are more acidic, owing to the leaching of bases (e.g. Ca^{2+}, Mg^{2+}, Na^+, and K^+) by rain and ground water. Soil pH is also temperature dependent; soils with high temperatures are more acidic and vice versa. Acidity/alkalinity influences the stability of chemical compounds, ion mobility, and organism activity within the soil deposit. Either highly acidic or alkaline conditions can speed up hydrolysis and the decomposition of organic matter (Cronyn 1990: 19).

There are several ways to measure soil pH, but Banning (2000: 243) suggests that electronic meters with glass reference electrodes are the best, most accurate means. A Hannah Instruments HI 9026 potentiometric pH meter was used in the present research. This meter uses a combination electrode that consists of two glass tubes housed in a larger plastic tube. The larger glass tube, which is called the measurement electrode, is filled with a KCl electrolyte (pH 7) and has a long, slim Ag electrode with an AgCl coated tip. Its end is a bulb coated with Li ions to create a semi-permeable membrane. This allows H^+ ions outside the membrane to react with the KCl in the measurement electrode, which creates a measurable voltage. The inner tube also contains a KCl electrolyte and an AgCl coated electrode. However, the solution in this tube maintains a constant chloride ion concentration that generates a constant voltage. This electrode acts as a reference, generating a pH of 7 and a voltage of 0 mV (Figure 3.2). The meter measures the voltage produced between the electrodes when they are placed into an unknown solution. The mV produced by the unknown solution corresponds to its pH

value (0 mV = pH 7; 59.2 mV = 1 pH unit). The meter used here has a range between -2 and 16 pH units and an accuracy of ±0.01. The instrument was calibrated using two buffer solutions (Hesse 1971: 24; Pansu and Gautheyrou 2006: 561-562). The pH buffers were a potassium phosphate – sodium hydroxide solution (pH 7) and a potassium hydrogen phthalate solution (pH 4).

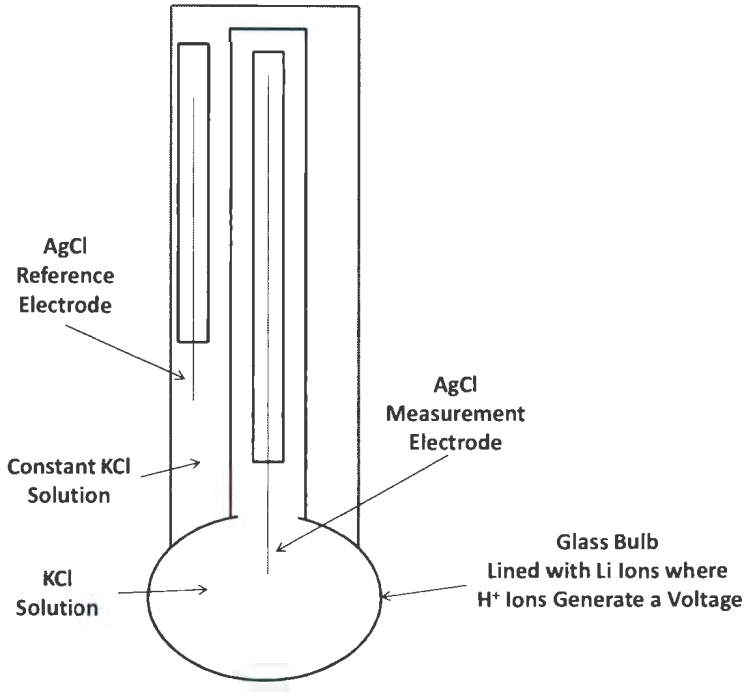


Figure 3.2: Diagram of a Combination pH Electrode

Before all analyses, the soil samples were air-dried in a sterile environment, which was a plexiglass chamber fitted with a Clean-Cell air circulation/filtration unit. The samples were spread onto brown paper sheets inside the chamber to facilitate even and timely drying. Once dry, macro-organic matter and rocks were removed from the samples. The samples were then disaggregated using a porcelain pedestal and mortar, and the fine earth fraction (<2 mm; clay, sand, and silt) was separated using 2 mm plastic

mesh. The samples were placed in a Siebtechnik ring and puck crusher for 60 seconds. The crusher is located in a separate facility with a dust removal system to avoid cross-contaminating the samples. A tungsten carbide bowl, ring, and puck, were used because the hardness of this metal increases the speed at which samples can be crushed while avoiding incorporation with the sample. If contamination from this equipment did occur, the only elements affected are W, Co, Ti, Ni, and Ta. All equipment was cleaned with silica sand and ethanol between soil samples to prevent cross-contamination (Entwistle and Abrahams 1997; Patnaik 2004; Cook et al. 2005).

The pH of each composite soil sample was measured in distilled water. Measurements taken from this type of solution are less acidic because of the generation of new cation exchange complexes (Limbrey 1975: 57). Using distilled water, which has a neutral pH, provides a value similar to the natural context. However, the water/soil ratio must be kept as low as possible, which can be a problem for organic soils. Adding too much water to the soil can cause more acidic readings. A 1:2 solution of pulverized soil to distilled water was used, which was 10 g of soil to 20 ml of water. However, ratios as high as 1:10 were necessary for some of the more organic samples. The samples were placed in Nalgene beakers, stirred intermittently for 30 minutes, and left to stand for 60 minutes. This allows the denser components to settle at the bottom, so measurements can be taken from the top, clear portion of the solution, which is referred to as the supernatant. The electrode was cleaned with distilled water between each test (Hendershot et al. 2008: 141-142). Duplicate samples were tested to assess analytical error. There is a negligible degree of error given the small range of values obtained in the duplicate pH tests (Table 3.1).

Table 3.1: Duplicate pH Testing for Analytical Error

Sample	pH Test 1	pH Test 2	pH Test 3
HbCh-1 House 2 Floor	5.30	5.25	5.36
IhCw-1 House 11 Platform	4.33	4.25	4.47
IhCw-1 House 9 Lamp Area	4.54	4.73	4.75

Reduction/oxidation potential, which is measured in mV, is used to characterize the availability of oxygen in soil systems. As with pH, Eh is measured as an intensity, not a concentration. The chemical reactions that occur in soil systems involve both proton and electron transfers. If atoms lose electrons, the reaction is classified as oxidizing, and if atoms gain electrons, the reaction is reducing. Oxidizing deposits are aerobic, meaning the addition of oxygen and loss of both H^+ and electrons causes oxidizing chemical reactions such as electrochemical corrosion. Conversely, reducing deposits are anaerobic; they emit electrons into to their surroundings, and they cause reduction reactions such as those induced by sulphate reducing bacteria. The Eh of a soil system influences ion mobility and the stability of specific chemically reactive compounds. It is also related to pH because H^+ ions are electron acceptors, so they participate in oxidation reactions. As the pH of a soil system increases, the Eh decreases. The Eh of soil typically ranges between -300 and +900 mV (Hesse 1971: 436-442, 458; Sparks 2003: 245-254; Pansu and Gautheyrou 2006: 581-584). Cronyn (1990: 21) offers the following classifications for soil Eh. Oxidizing deposits produce readings between +700 and +400 mV. Moderately reducing deposits have values between +399 and +100 mV. Reducing deposits have values between +99 and -100 mV. Highly reducing deposits range between -101 and -300 mV.

The meter used to measure pH was also used to measure Eh. However, using this meter to measure Eh requires a platinum electrode. Reduction/oxidation potential electrodes are factory calibrated, making them easy to use. They measure Eh using the difference between the potential of H^+ ions and a platinum electrode when the electrode is placed into a solution. The electrode used here contains a solution with a known redox potential. When the electrode is placed into oxidizing solutions, the platinum tip releases electrons into the solution, gains a positive charge, and generates positive voltages. The platinum tip of the electrode gains a positive potential relative to the solution. If the unknown solution is reducing, the electrode receives electrons from the solution, gains a negative charge, and produces negative voltages. The electrode gains a negative potential relative to the solution (Hesse 1971: 438; Sparks 2003: 253; Pansu and Gautheyrou 2006: 581). The Hannah Instruments HI 9026 has a range between -2000 and +2000 mV and an accuracy of ±1 mV. The same procedure employed for pH was used to test Eh. Duplicate testing produced values with a small range, indicating a small degree of analytical error (Table 3.2).

Table 3.2: Duplicate Eh Testing for Analytical Error

Sample	Eh Test 1	Eh Test 2	Eh Test 3
HbCh-1 House 2 Floor	240.3 mV	250.2 mV	232.2 mV
IhCw-1 House 11 Platform	314.2 mV	317.9 mV	302.7 mV
IhCw-1 House 9 Lamp Area	231.5 mV	257.7 mV	230.4 mV

The salinity of a solution, which is its concentration of dissolved salts, is measured using salinity indices such as TDS and EC. Total dissolved solids is a measurement of a solution's concentration of dissolved minerals, salts, and metals, or the

sum of its cations and anions. This soil property can be measured indirectly using EC. The EC of a soil system refers to its ability to conduct electrical currents. Soils that are good conductors of electricity have large amounts of soluble salts, or dissolved solids, which can speed up chemical reactions such as corrosion. The measurement device consists of a negatively charged electrode and a positively charged electrode. When these electrodes are placed into a solution and a voltage is applied across them, positively charged ions gravitate toward the negative pole and negatively charged ions toward the positive pole. An electrical current is created by these moving ions, which is measured by the meter in μS/cm. This is the EC of the solution, which is converted to TDS using a multiplication factor of 0.5 (Sparks 2003: 288-291).

As with pH and Eh, the TDS of the soil samples underwent measurement in a 1:2 solution of prepared soil to distilled water. Distilled water has 0 TDS. A Hannah Instruments HI 9810 TDS/EC meter was used to take the measurements. This meter has a range of 0 to 3000 ppm (1 ppm = 1 mg/kg) and an accuracy of ±2%. Measurements are taken with an electrode similar to the one used to measure pH above. The electrode was calibrated using a solution having a known TDS content. In this case, a solution with a TDS concentration of 1383 ppm was used. Duplicate testing identified a negligible degree of analytical error, given the small range of values obtained (Table 3.3).

Table 3.3: Duplicate TDS Testing for Analytical Error

Sample	TDS Test 1	TDS Test 2	TDS Test 3
HbCh-1 House 2 Floor	800 ppm	850 ppm	770 ppm
IhCw-1 House 11 Platform	80 ppm	80 ppm	90 ppm
IhCw-1 House 9 Lamp Area	110 ppm	110 ppm	110 ppm

The most common source of error encountered when testing pH, Eh, and TDS is electrode contamination. Readings can fluctuate if the electrode is dirty, improperly stored, or poorly calibrated. As mentioned, electrodes were cleaned both during and between tests using distilled water. This will reduce error stemming from electrode contamination. Because the supernatant is measured, errors from the suspension effect can also occur. If the suspension is too cloudy, or the electrode is exposed to the settled sediment, the instrument can become contaminated or clogged, meaning inaccurate readings can be produced (Pansu and Gautheyrou 2006: 566). Tests were conducted only once the supernatant was sufficiently clear. Additionally, as mentioned, duplicate tests were conducted to assess analytical error.

X-Ray Fluorescence

X-ray fluorescence rapidly measures multiple elements in crystalline solids, including soils, which is useful for identifying, delimiting, and mapping archaeological sites (Gardner 1990; Wilson et al. 2008). The arrangement of an element's atoms, or its atomic structure, is unique and can be identified using XRF (Jenkins 1988; McMurry and Fay 2003). During the XRF procedure, crystalline solids are bombarded with x-rays, causing them to emit secondary fluorescent spectra indicative of the elements present. X-rays are defined as the portion of the electromagnetic spectrum having wavelengths between 0.1 and 100 Å. X-rays can also be defined as photons of energy expressed as keV. When bombarded with x-rays, the atoms comprising each element present in a given sample absorb a quantity of x-radiation, subsequently displacing electrons from their inner shells. If a free electron collides with an atomically bound electron, and the free electron has more energy than the bound one, the bound electron is knocked out of

position and becomes a photoelectron (Jenkins 1988: 4-5; Rouessac and Rouessac 2000: 237-243). This photoelectric absorption forces the atoms into excited states. When the missing inner shell electrons are replaced by ones from outer shells, the atom's stored energy is released as both continuous and characteristic fluorescent x-rays. The characteristic x-ray spectrum is used in XRF. These x-rays are either scattered coherently or incoherently, meaning there is no loss in energy or a small energy loss respectively. Incoherently scattered x-rays have increased wavelengths and are not useful for identifying atomic structures (Williams 1987: 10-15, 34).

In a given sample, each element produces a characteristic fluorescent x-ray wavelength with an intensity indicative of its proportion (Lewis and McConchie 1994: 173-174; Garrison 2003: 215). Reference crystals are used to diffract fluorescent x-ray beams, allowing the calculation of their wavelengths. When an x-ray collides with a crystalline surface, a portion of it is scatted in all directions and destroyed by interference. However, certain angles of diffraction can sustain scattered x-rays. This is called x-ray diffraction, which enables the measurement of an x-ray's wavelength. To successfully diffract an x-ray, the planes of the reference crystal must have equal angles, the directions of the incident and secondary beams must be coplanar, and the beams reflected from the crystal planes must have differing wavelengths (Bertin 1978: 71; Rouessac and Rouessac 2000: 245). Bragg's law ($n\lambda = 2c \sin\theta$) is used to identify the atomic structures of crystalline solids using the wavelengths they emit when excited. The manner in which an x-ray diffracts from the cleavage planes of a given reference crystal can be used to calculate the wavelength of that x-ray. The diffracted angle of incidence is the theta

(θ) value. The d variable is the distance between the atomic layers in a given crystal. The lambda value (λ) is the wavelength of the incident x-ray beam. The n variable is an integer representing the order of diffraction (Patnaik 2004). Reference crystals behave like stacked mirrors that are cut parallel to a system of diffracting planes having known interplanar d spacing. The generated, incident x-ray is directed toward the reference crystal at known θ angles (between 0 and 90^0). Since the d spacing and θ angles are known, λ can be calculated (Williams 1987: 47). Common reference crystals include topaz, lithium fluoride, silicon, graphite, and mica (Rouessac and Rouessac 2000: 245).

For XRF, the soil samples underwent the preparation process described above. Samples were pulverized and consolidated to reduce and homogenize their grain size (Bertin 1978: 405-407; Jenkins 1988: 108). Materials that will not contaminate the samples such as tungsten carbide crushing equipment and resin binders should be used. Five grams of each powdered sample was combined with a binding agent, which was 0.7 g of phenolic resin (Injuk et al. 2006). The samples were pressed into pellets using 20 ton/in^2 of pressure for 10 seconds in a Herzog press. Lastly, the pressed pellets were baked at 200^0C for 15 minutes. Finely ground, pressed powder samples provide more intense fluorescent x-rays, and thus greater analytical sensitivity. They also provide results with greater reproducibility (Tertian and Claisse 1982: 320).

A Fisons/Applies Research Laboratories 8420+ sequential wavelength-dispersive x-ray spectrometer was used in this research. The 8420+ has one goniometer that holds up to six analyzing crystals at once. The element detection system consists of an argon/methane flow proportional counter and a scintillation counter. The x-ray detector

converts the energy from the x-ray's photons into pulses that are counted. The response given by the detector is proportional to the energies of the detected photons. Flow proportional detectors, such as the argon/methane counter used here, contain an inert, ionized gas. Electrons produced by the ionization of this gas migrate toward an anode where they produce voltage pulses that are counted by a computer. Scintillation counters detect fluorescent x-rays by forcing a reaction between the x-ray's photons and a phosphor material. This causes valence-band electrons to reach higher energy levels. When the electrons revert to their normal state, this energy is emitted as visible light, which is converted to voltage pulses by a photomultiplier (Figure 3.3) (Williams 1987: 58-59). Results are given in ppm for pure elements and percent weight for oxides such as Na, Ca, K, and Fe. Most elements have detections limits of less than 1 ppm (Pam King, Pers. Comm.). Here, the elements identified with XRF are Na, Mg, Al, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Ce, Pb, and Th.

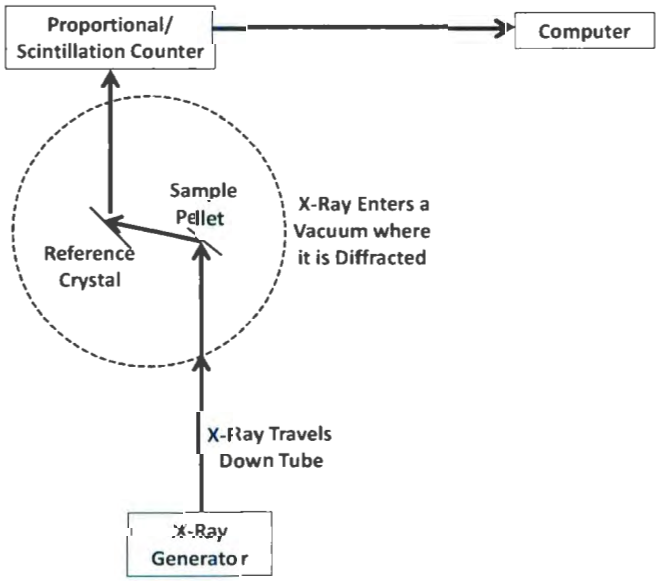


Figure 3.3: Diagram of XRF Instrumentation (Adapted from Lewis and McConchie 1994)

The accuracy of XRF is typically around ±0.5% (Tykot and Young 1996: 119). A negligible amount of analytical error (i.e. the obtained values have very low ranges) was identified using repeated measurements of standard soil reference solutions, specifically SO-2 and PACS-1 (Table 3.4). Standard geological reference materials were also tested and compared to internationally accepted values. These were the DTS-1, AGV-1, BHVO-1, SY-2, SY-3, and BCR-1 standards (Govindaraju 1989). The codes represent the referenced material and its collection location. For example, the BCR-1 standard is basalt from the Colorado River 1 location. These tests certify the instrument, ensuring that it is working properly and producing accurate and precise results.

Table 3.4: Test for XRF Analytical Error using Duplicate Tests of Geological Standards

	DTS-1			**BHVO-1**		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Na	0.15%	0.15%	0.16%	2.29%	2.31%	2.28%
P	0.11%	0.11%	0.11%	0.30%	0.30%	0.29%
S	1131 ppm	1112 ppm	1138 ppm	1085 ppm	1064 ppm	1070 ppm
Cl	721 ppm	727 ppm	710 ppm	1014 ppm	1014 ppm	984 ppm

Jenkins et al. (1981: 327) state that errors in the XRF technique are either random or systematic. Random errors can arise from issues with counting techniques such as using a poorly calibrated detector. Systematic errors occur either because of issues with the sample (e.g. preparation technique) or instrumentation (e.g. x-ray tube contamination, crystal deterioration, or sample positioning). Another potential problem with XRF is misclassification, which is when an emitted wavelength for a given compound is similar to the wavelength characteristic of another element (Lewis and McConchie 1994: 174). Additionally, problems with mass absorption may arise. Variation in mass absorption

between samples is influenced by pressed pellet formation. If the grain sizes and smoothness of the pellets vary between samples, mass absorption will also vary, which can cause poor results (Muller 1972: 127; Gardner 1990: 169). Perhaps the most common sources of error in XRF are matrix effects. When one element, or analyte, is considered at a time, the matrix is defined as the analytes not being measured. There are two common types of matrix effects, which are primary-absorption effects and secondary-absorption effects. The primary-absorption effect occurs when elements other than the analyte absorb a large amount of the primary x-ray used to excite the atoms. This can cause the analyte to absorb too little of the primary x-ray, which can make concentrations appear lower or higher than they actually are. Conversely, in the secondary-absorption effect, the matrix elements absorb too much of the secondary, fluorescent x-rays used to determine concentrations, which can also cause higher or lower x-ray absorption coefficients and thus higher or lower elemental concentrations (Bertin 1978: 281-282; Jenkins 1988: 134).

Inductively Coupled Plasma – Mass Spectroscopy

Numerous researchers, including Entwistle and Abrahams (1997), Cook et al. (2004), and Wilson et al. (2008) have used ICP-MS to measure the geochemical compositions of archaeological soils. Using ICP-MS to identify the composition of archaeological soils has many advantages over other techniques. Only a small amount of powdered material is required (0.5 g), making it a minimally destructive technique. Multiple elements can undergo measurement simultaneously and rapidly, which is useful for characterization and provenance research (Lewis and McConchie 1994: 178; Tykot and Young 1996: 117, 118). Inductively coupled plasma-mass spectroscopy is also the

most accurate method for identifying trace element concentrations in soils such as the rare earth elements because it has very low detection limits (Date and Jarvis 1989: 51, 53).

This analytical technique identifies the concentrations of elements in a liquid sample using their atomic masses. Each element in the solution has a characteristic atomic mass, which is the sum of the masses of its protons, neutrons, and electrons. Liquid samples are subjected to an ICP torch that produces an 8000^{0}C fireball using an argon gas flow (Garrison 2003: 227, 229). This heat source is coupled with a copper load coil, which maintains a constant energy output using a radio frequency generator. The plasma (an ionized gas containing free electrons) is emitted from a quartz tube at the mouth of the torch. The area of the plasma used to measure elemental concentrations is blue in colour and approximately 20 mm long by 5 mm wide. The liquid samples are introduced to the plasma using a high velocity argon gas flow distributor, which sprays droplets smaller than 8 μm onto the plasma (Jarvis et al. 1992: 10, 14). This atomizes and ionizes the sample, causing it to gain individual positively charged ions, which are atoms that have lost at least one electron. These ions are vacuumed through a quadrupole mass spectrometer at velocities determined by their individual energies and masses. Quadrupole mass spectrometers measure the mass to charge ratio of the ions in a focused beam travelling through a vacuum sealed flight tube. The ion beam travels across four quadrupoles, or electrodes, that generate an oscillating magnetic field. The ions pass into a curved flight tube, where an electromagnet separates them according to their mass/charge ratios. Ions are detected and counted using an electron multiplier, converting the ion beam into electrons. When the travelling ions collide with a conversion plate, they eject electrons that are accelerated using a known voltage. The electrons are typically

multiplied using either a continuous or discrete dynode and counted as electrical pulses by a computer (Rouessac and Rouessac 2000: 314-315; O'Conner and Evans 2007: 151-152). Elements have characteristic mass to charge ratios, which is how ICP-MS identifies the chemical compositions of liquid samples (Gray 1989: 12-15; O'Conner and Evans 2007: 143). Elemental concentrations derived from this type of analysis are reported in ppm.

As with the analyses discussed above, samples for ICP-MS were air-dried, disaggregated, and screened using a 2 mm plastic mesh to separate the fine earth fraction. The fine earth fraction was pulverized using a tungsten carbide ring and puck mill (Entwistle and Abrahams 1997; Cook et al. 2005). Following Jenner et al. (1990) and Longerich et al. (1990), 0.5 g of each sample was mixed with a 2-3 ml solution of concentrated HNO_3 and HF in individual Teflon beakers. These acids were chosen for sample dissolution because of the elements under examination. Nitric acid is the most widely used digestion acid, owing to its highly oxidizing properties, meaning it dissolves trace elements in most minerals. The HF is combined with HNO_3 to complete the dissolution of metals. Additionally, HF is the only acid that will easily dissolve silica based minerals. The capped beakers were placed on a hot plate for sample dissolution and evaporation. This is referred to as an acid digestion bomb, in which element dissolution is hastened by heat and pressure. This method produces a more completely dissolved solution without destroying trace elements (Jarvis et al. 1992: 174, 177, 192). Once evaporation was complete, the samples were placed into Nalgene bottles with a 2-3 ml solution of 8 *N* HNO_3 and diluted with Millipore prepared water to a weight of 90 g. An aliquot of 1 ml underwent analysis. A HP 4500+ ICP-MS instrument was used in this

analysis. The elements analyzed are Li, Rb, Sr, Zr, Nb, Mo, Cs, Ba, Hf, Ta, Ti, Pb, Th, Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu. However, ICP-MS was primarily used to identify trace concentrations (less than 100 ppm) of rare earth elements, which are Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu.

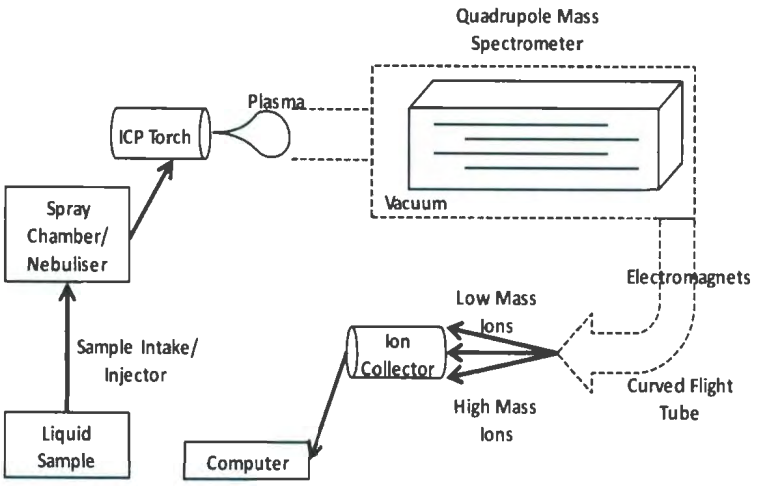


Figure 3.4: Diagram of ICP-MS Instrumentation (Adapted from Garrison 2003)

The accuracy of ICP-MS typically ranges between ±2% and 4% (Tykot and Young 1996: 116). The instrumentation used in this study, when coupled with several international geochemical standards, yields results having precisions between 3% and 7% (Pam King, Pers. Comm.). Analytical error was assessed through duplicate measurements of a standard soil reference solution (SO-2) and archaeological soils samples. The range of values obtained through duplicate testing was moderate, indicating a moderate degree of error (Table 3.5). Standard geological reference materials (MRG-1, DNC-1, W-2, DTS-1, PCC-1, AGV-1, STM-1, BHVO-1, and BCR-1) were also tested and compared to internationally accepted values (Govindaraju 1989). These tests ensure the instrument is producing accurate and precise measurements.

Table 3.5: Test for ICP-MS Analytical Error using Duplicate Soil Samples

	M29990T		M29989L	
	Test 1	Test 2	Test 1	Test 2
Pr	2.426 ppm	2.688 ppm	3.118 ppm	4.116 ppm
Nd	10.018 ppm	10.694 ppm	11.328 ppm	14.900 ppm
Sm	2.306 ppm	2.535 ppm	1.797 ppm	2.394 ppm
Eu	0.681 ppm	0.744 ppm	0.561 ppm	0.577 ppm

Additionally, chondrite normalization was used to ensure that rare earth element concentrations are accurately represented. Given their similar chemical characteristics, these elements act as a group, making accurate calculations of their concentrations difficult. Since this is the case, rare earth data are typically standardized by dividing their average abundance by their abundance in a chondrite meteorite sample (Entwistle and Abrahams 1997). Here, rare earth element data underwent standardization using chondrite data from Taylor and McLennan (1985: 298).

Matrix interferences and spectral interferences are problems that must be solved to obtain useful ICP-MS data (Thompson and Walsh 1983: 25-33; O'Conner and Evans 2007: 153). Matrix interferences can occur because of poor sample dissolution. If samples having high TDS are introduced into the plasma, the accuracy of the machine is compromised because these solids can become deposited on the instrument, reducing its sensitivity. Spectral interferences occur when compounds mimic the nominal masses of other elements. Elements in the digested soil solution can react with the argon gas used to create the plasma, creating new compounds having similar nominal masses to other individual element species. Drift may also be a problem, which is a change in the sensitivity of specific elements over time. That is, if prepared solutions are not tested in a timely manner, their elemental concentrations could be inaccurate. Here, correction

factors such as the method of standard addition were used to solve these problems. These techniques are explained fully in Jenner et al. (1990) and Longerich et al. (1990).

Summary

This chapter described the field and laboratory methods employed to identify Inuit influences on soil chemistry in northern Labrador. The field methods described were mapping, stratigraphic profiling, and soil sampling. A total station was used to map the Iglosiatik and Komaktorvik sites. Soil samples were extracted from features visible on the ground surface using a stainless steel corer, excepted for the Nachvak samples, which were collected during excavation. Several samples from each feature were combined to create a composite, representative samples. The laboratory methods used are soil texture, soil colour, pH, Eh, TDS, XRF, and ICP-MS. Soil texture and colour were assessed qualitatively using texture chart and the Munsell soil colour chart respectively. The pH, Eh, and TDS of the samples were measured using electronic meters with chemically referenced electrodes. X-ray fluorescence and ICP-MS were respectively conducted by Pam King and Jiggs Digor from the Memorial University Department of Earth Sciences (Analytical Geochemistry Group). X-ray fluorescence quantified concentrations of Na, Mg, Al, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Ce, Pb, and Th. Inductively coupled plasma-mass spectroscopy identified concentrations of Li, Rb, Sr, Zr, Nb, Mo, Cs, Ba, Hf, Ta, Ti, Pb, Th, Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu. Potential sources of error for the analytical techniques were also identified. Duplicate testing for each analytical technique shows a minimal amount of error for most of the variables. The ICP-MS readings for the elements Pr, Nd, and Sm, however, have a moderate degree of error. Considering this, the majority of the results

obtained from the instruments are both accurate and precise. Another problem encountered in the XRF and ICP-MS analyses was low Zr dissolution (Pam King, Pers. Comm.). Given these problems with Pr, Nd, Sm, and Zr, caution must be exercised when interpreting human influences on them. Data collected using the methods described above are described and analyzed in the following two chapters and appendices.

CHAPTER FOUR

UNDERSTANDING AND SAMPLING INUIT WINTER DWELLINGS

Many of Canada's Arctic and Subarctic landscapes contain archaeological evidence of the lifeways of Thule Inuit people. Elaborately built whale bone houses, vast assemblages of finely made hunting equipment, deep middens brimming with the bones of various prey, ceremonial/sacred structures, and items of adornment expressing individuality attest to the vivid lives and beliefs of these people. This chapter briefly reviews the development of the Thule Inuit culture, emphasizing their winter dwellings, which, in this present research, is useful for properly identifying dwelling features (e.g. floors, platforms, lamp areas, tunnels, and middens) for soil sampling. I also describe the dwellings and soils tested for the present research. The tested sites are discussed in order of increasing latitude. Two houses were sampled at Iglosiatik Island (HbCh-1), one at Nachvak Fiord (IgCx-3), three at Komaktorvik Fiord (IhCw-1), and one at Big Head (IiCw-1). Additionally, soils were collected from two middens at Nachvak, one at Komaktorvik, and one at Big Head.

The Thule Inuit: Ancestors of the Labrador Inuit

Archaeologists distinguish four (somewhat arbitrary) periods of Thule Inuit culture history, which are Pioneering (A.D. 1000-1200), Classic (A.D. 1200-1400), Modified (A.D. 1400-1700), and Historic Inuit (ca.1600-1900 in Labrador) (Schledermann 1971: i; Whitridge 1999: 65-78, 2001: 5; Whitridge Pers. Comm.). Archaeologically speaking, these people were named after the Thule District of Greenland, which is where their material culture was first identified (McCartney 1979a:

3; Maxwell 1985: 247). In 1927, Mathiassen, chief archaeologist of the seminal Fifth Thule Expedition to Arctic Canada (1921-1924), used the name Thule to distinguish an Inuit culture having a maritime adapted hunting and gathering mode of economy (de Laguna 1979: 11).

Mathiassen (1927, 1930) was also among the first to hypothesize about the origin of Thule people and their subsequent eastward migration. Based on similarities in material culture between Thule and Asiatic groups, he speculated that Thule people were the descendents of migratory Asiatic people who entered Alaska through Siberia. Considering radiocarbon dates, the appearance of Natchuk and Thule II harpoon heads in both Birnirk and Early Thule contexts, and similarities in other types of material culture, Taylor (1963) later hypothesized that Thule people were the descendents of Alaskan Birnirk people. He argued that Birnirk people extended their territory into Amundsen Gulf by A.D. 900, where they adopted new technologies for hunting bowhead whales. The transition from Birnirk to Early Thule likely occurred between A.D. 900 and 1000. During the Medieval Warm Period (A.D. 800 - 1300), sea ice decreased drastically, providing an ideal habitat for large and predictable bowhead populations, which McGhee (1990) argues led to both Punuk and Birnirk innovations for their capture. McGhee agrees (1972, 1990) that both Birnirk and Early Thule people used Natchuk style harpoon heads, but adds that the Thule whaling harpoon float was a Punuk innovation, suggesting Thule culture developed from a combination of both Birnirk and Punuk influences.

The Pearce Point Site (NkRh-3), which is on the west coast of Amundsen Gulf, dates to the beginning of the Pioneering Thule period (Morrison 2000: 254). House 4 at NkRh-3 is a definitive example of a Thule winter dwelling from this period. Built directly

on the surface of the ground, this house is rectangular and has a perimeter of small post-holes that held straight driftwood logs, indicating a portico roof. This house is not semi-subterranean and does not have a raised sleeping platform. The floor, covering an approximate area of 12 m^2, is planked with wood. The entrance passage is slightly depressed and flanked with wooden planks. The lack of post-holes around the entrance passage suggests it had a light skin roof fastened to the ground with rocks. Perhaps the most interesting feature of this dwelling is the detached kitchen area. This area measures approximately 4 m^2 and was roofed with a skin tent, indicated by the presence of an open hearth feature and the absence of perimeter defining post-holes (Morrison 2000: 223-224). Interestingly, this dwelling has commonalities with Birnirk winter dwellings. For example, the wooden plank floor, portico roof, and kitchen annex are common features found in Birnirk winter dwellings, strengthening the claim that Thule people are the descendents of Birnirk people (LeMouel and LeMouel 2001: 178, 180, 183).

Thule groups migrated eastward across the Arctic archipelago into Greenland around A.D. 1200 (Taylor 1963: 459-460; Dugmore et al. 2007: 18). Both an increased demand for food resources and mobility could have stimulated this migration across the Arctic. Perhaps Thule people expanded into new territory and persisted there until demographic pressures stimulated a move into other locations (Morrison 2000: 222). Between A.D. 1200 and 1400, the Canadian Arctic and Greenland were inhabited by people archaeologists refer to as Classic Thule. Maxwell (1985: 283-289) describes Classic Thule whale bone dwellings as ovoid, with a flagstone paved, semi-subterranean floors. Their superstructures consisted of rock supported whale bone rafters, covered with skins, sods, and snow. They had raised sleeping platforms in their rear portions covered

with a baleen mattress and caribou skins. These houses typically contained one or two lamp platforms, or a kitchen niche, and several storage lockers. Perhaps most interestingly, and opposed to earlier Thule dwellings, Classic Thule dwellings have three interior levels used for thermoregulation. The lowest is the entrance tunnel, which is excavated approximately 1 m below the ground surface. The paved floor is approximately 50 cm above the entrance tunnel floor. Lastly, the sleeping platform is approximately 50 cm above the living floor (Park 1997).

Park (1997) provides a thorough description of a Classic Thule winter dwelling at the Porden Point site (RbJr-1), which is on Devon Island in the High Arctic. Based on radiocarbon dates and the appearance of Thule II harpoon heads, the site was likely occupied around the beginning of the Classic Period. Opposing Pioneering Thule winter dwellings, House 13 at RbJr-1 is semi-subterranean, sub-rectangular in shape, and has a low wall berm around its perimeter fashioned from sod, stone, and sediment. Moreover, this dwelling had a domed roof constructed from whale bone, sod, and snow. Superstructural elements were set into crevices created by large piles of stones rather than earthen post-holes. The six bowhead mandibles, 32 maxillae, and 54 ribs that comprised the superstructure of House 13 were relatively undisturbed. The flagstone interior is approximately 8 m^2, which is rather small considering that some dwellings from this period measure up to 20 m^2. The sleeping platform is raised about 50 cm above the floor, is paved with flagstones, and occupies approximately 60% of the interior. There are also two storage niches below the platform. The kitchen annexes common in earlier Thule dwellings were reduced to a niche during the Classic period. House 13 has a single

kitchen niche adjacent to its entrance tunnel. The entrance tunnel is approximately 50 cm below the floor, 1 m wide, and 3 m long (Park 1997: 277-281).

Thule people rapidly expanded as far south as the Hudson Strait (Maxwell 1985: 261; Whitridge 1999: 80-85). This gave way to the archaeologically defined Modified Thule period, which dates roughly between A.D. 1400 and 1700. During the Modified period, Thule people abandoned the High Arctic and expanded as far south as Quebec and Labrador. Some winter settlements moved on to pack ice where people dwelled in snow houses and practiced breathing hole sealing. Some dwellings from this period are archaeologically similar to the Classic dwellings described above. However, several architectural variants have been documented, including bilobate and trilobate forms. The locations of lamp areas have also changed over time. This suggests that Inuit houses were continually reconceptualized and remodelled, specifically regarding the integration of gendered spaces (Whitridge 2008). Moreover, lower frequencies of whale elements and baleen in contexts later than A.D. 1400 represent a decline in the importance of whaling (Maxwell 1985: 304).

The Labrador Inuit

Likely arriving via dog-drawn *komatik* and *umiak*, Thule Inuit people began to populate major island and fiord systems in northern Labrador around A.D. 1450 where they practiced a maritime oriented subsistence economy (Kaplan 1980: 648; Whitridge Pers. Comm.). Caribou and bird remains are also found in their middens. They typically chose settlement locations near the *sina* (ice edge) and polynyas, which are ice-free zones where people could capture seals and launch their boats (Schledermann 1971: 69;

Fitzhugh 1980a: 601). By the early 17th century, Labrador Inuit people expanded as far south as Groswater Bay (Kaplan 1985: 48, 50).

Between the 15th and late 17th centuries, Labrador Inuit people spent their winters living in ovoid, semi-subterranean houses constructed from turf, stone, whale bone, and timber (Kaplan 1983: 234, 1985: 52; Woollett 1999: 371). Houses during this period often had a single room, but bilobate and trilobate forms have also been documented. The Thule/Labrador Inuit structures that Bird (1945) describes at Avertok, Anniowaktook, Napatalik, Karmakullk, and Iglosoataligarsuk, are similar to those constructed by Classic Thule people. Specifically, the morphology of House 2 at Avertok (GiCb-1) is similar to the winter dwellings constructed by Classic Thule people. House 2 has an ovoid shape, paved flagstone floor, and a rear sleeping platform. The interior of the dwelling covers approximately 10 m^2. The rear platform occupies 60% of the interior, measuring about 6 m^2. The cold-trap entrance tunnel is approximately 1 m wide and 4 m long. This house also has two lamp areas near the edge of the platform, indicated by accumulations of fat and oil in the associated soil. This type of dwelling was typically occupied by a single family between the late fall and early spring. Schledermann (1971: 44) describes a similar house from the Ikkusik site (IdCr-2) as "pear-shaped". House 15 at Ikkusik has a paved flagstone floor, a rear platform, and a cold-trap entrance tunnel. Its interior covers an area approximately 20 m^2 and the tunnel is 1.5 m wide and 4 m long.

The 18th century was a period of significant change for Inuit people in northern Labrador. Increasing contacts with Europeans and use of their materials may have caused a shift in traditional Inuit economy, which could have contributed to the development of the large multifamily houses used to define this period (Woollett 1999: 371). Perhaps this

shift in winter dwelling form represents a risk management strategy, demonstrating the urgency of maintaining social cohesiveness and cultural identity among the increasing presence of European, and even Inuit, strangers (Kaplan and Woollett 2000: 357). Whale elements are sparse in house construction during this period, which could represent a decline in the socioeconomic importance of whale hunting (Schledermann 1971: 111).

Schledermann (1971) offers a classic description of Labrador Inuit communal dwellings in Saglek Bay. House 8 at the Ikkusik site (IdCr-2), for example, is diagnostic of Labrador Inuit communal dwellings. Communal dwellings have a different shape, sleeping platform arrangement, and superstructure compared to early Labrador Inuit winter houses. House 8 is rectangular, and the floor is paved with flagstones, covering an approximate area of 55 m^2, which is much larger than the houses used in the Classic and Modified periods. Instead of one sleeping platform, this dwelling has three. It has one rear platform and two side platforms. The platforms are also larger than their predecessors, covering a cumulative area of about 24 m^2. The entrance tunnel is slightly less than a meter wide and around 3.5 m long. Six lamp platforms were also identified inside this dwelling. The superstructure was pitched on four sides rather than domed, consisting of mostly logs and sods. However, other communal dwellings have incorporated some whale bone elements (Schledermann 1971: 77-79).

During the 19th century, Labrador Inuit people reverted to constructing smaller winter dwellings. These houses retain features such as cold-trap tunnels, paved flagstone floors, and rear sleeping platforms. However, their construction often incorporated more European materials such as cast iron stoves and window glass. The 19th century sod house Schledermann (1971: 116) investigated at the Tuglavina site (IdCr-1) is sub-rectangular,

has a plank floor, and has an interior area of 21 m^2. It also has a small storage alcove in its southwest corner that is paved with flagstones. The tunnel is approximately 1m wide and 4 m long.

The Thule and Labrador Inuit dwellings described above are similar to those investigated in the present research, and are useful comparative sources for identifying the internal features of the houses under exploration. The dwellings I investigated at Iglosiatik, Nachvak, Komaktorvik, and Big Head are discussed below. The Iglosiatik and Nachvak investigations were directed by Dr. Peter Whitridge (Memorial University of Newfoundland). The Komaktorvik and Big Head investigations were co-directed by Dr. Peter Whitridge and Dr. James Woollett (Laval University).

Archaeopedological Research in Labrador's Barrens and Mountains[2]

Since this is the first archaeopedological study conducted in Labrador, two ecoregions (i.e. Coastal Barrens and Low Arctic Torngats) with a wealth of Inuit archaeological resources are explored. Identifying the local topography, vegetation, geology, and pedology at each site is necessary for understanding the differences between natural and archaeological soils, and subsequently identifying suitable control areas. Labrador's Coastal Barren ecoregion is comprised of sheltered inlets and islands between Napaktok Bay and the Strait of Belle Isle. The average winter and annual temperatures are -13^{0}C and -3^{0}C respectively. The summer growing season is between 100 and 120 days long (Bell 2002; NL Natural Resources 2007). Annually, there are between 70 and 80 frost-free days (Whitridge 2001: 22). Forested areas, consisting mainly of white spruce with a moss understory, are sparse. The majority of the Coastal Barren ecoregion is

[2] Chemical data for Iglosiatik, Nachvak, Komaktorvik, and Big Head soils are reported in Appendix A.

scrubland, consisting mainly of dwarf willow and birch, alpine heath, lichens, and sedge grasses (Kaplan 1983: 66; Bell 2002; NL Natural Resources 2007). These plants, in varying stages of decomposition, contribute to the thin humus layer typically found on the surface of soil deposits in this area.

Iglosiatik Island is located in this region, which is also a part of the Nain Geological Province. The geology of Iglosiatik Island consists of tonalitic and granitic gneisses formed between the eoarchean and the paleoarchean (4.0 to 3.2 billion years ago) through regional dynamothermal metamorphism and orogenisis (NL Geological Survey N.D.). The major mineral constituents of these gneisses, which are the parent materials for the soils in the area, are quartz, orthoclase feldspar, biotite, amphibole, and pyroxene. The elements comprising the structure of these minerals can appear in large quantities in Iglosiatik soil systems. Considering the elemental compositions of these minerals, Ca, Na, Mg, Fe, Al, Si, and K are likely the primary elemental constituents of Iglosiatik soils (Chesterman and Lowe 1979: 502, 508, 533, 539, 735-737). Considering this, caution must be exercised when interpreting eutrophication of these elements in soils from the HbCh-1 archaeological site.

Based on soil coring and soil horizon profiles, the soil system at HbCh-1 appears to belong to the cryosolic order. These types of soils are prevalent beyond the tree line, in the northern third of Canada. They typically have both mineral and organic horizons and permafrost layers or patches within 1 to 2 m of the surface (CCWG 1998: 73). Permafrost in the Coastal Barrens typically occurs in isolated patches (Bell 2002). Permafrost was not encountered during the 2007 investigations of HbCh-1. The soil profile considered at Iglosiatik appears to belong to the gelysolic turbic suborder. This suborder is

characterized by a mean annual temperature of 0^0C, a thin organic surface horizon, a gleayed horizon (a layer forming near the surface with a light grey colour because of eluviation of organic matter and clay minerals), and mixed, disrupted, or broken horizons caused by cryoturbation (churning caused by the presence of permafrost and freeze-thaw cycles) (CCWG 1998: 12-16, 76). All of these features are present in the profile considered at HbCh-1 (Figure 4.1). The upper horizon (Om) is a thin layer of sod and accumulated organic matter in varying stages of decomposition. The next horizon (Aeg) is a gleayed mineral horizon having its clay minerals (e.g. Fe and Al) and organic matter eluviated further into the system. Below Aeg are Bhy and Bmy. The Bhy horizon is a mineral horizon enriched with organic material and minerals from the upper horizons. This horizon has particularly large accumulations of Fe, indicated by its dark brown colour. The Bmy horizon is a mineral horizon altered by hydrolysis, causing a dark, mottled appearance. The disrupted and intrusive layers suggest moderate cryoturbation. The gelysolic turbic suborder also shares some similarities with the gelysolic order. For instance, at Iglosiatik, the deposit is somewhat mottled, likely because of the high groundwater table, which is only 60 cm below the surface (CCWG 1998: 81, 82).

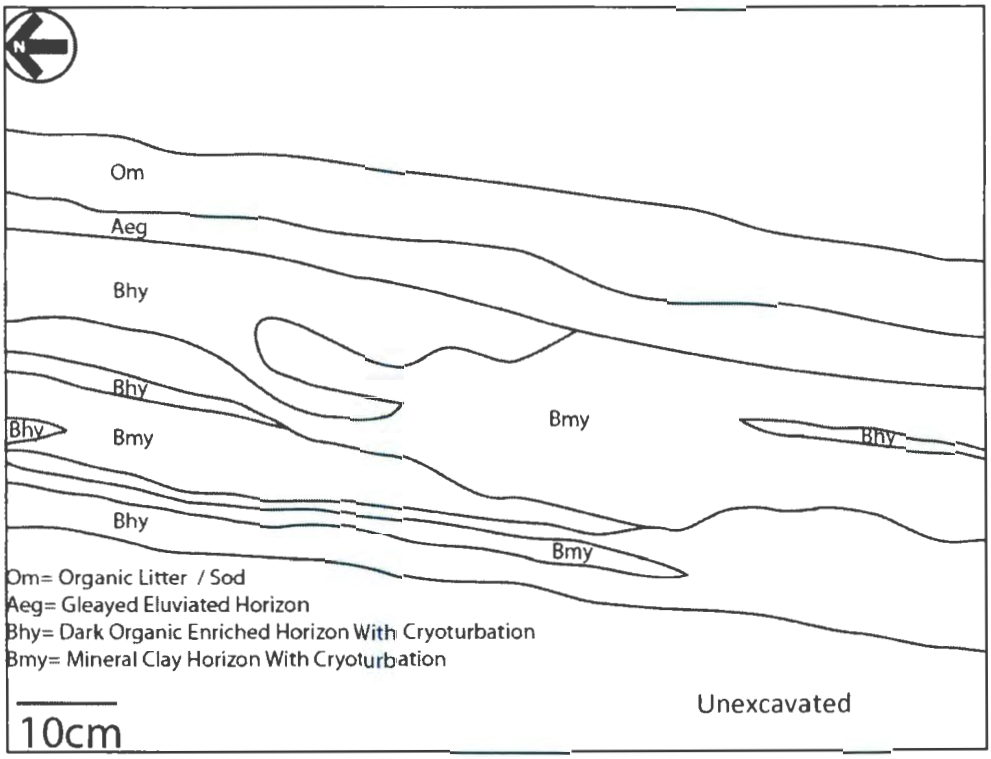


Figure 4.1: Soil Profile of the East Wall of Test Unit 3 at Iglosiatik

The Nachvak, Komaktorvik, and Big Head sites are in the Torngat Mountains, which are a part of the Low Arctic Torngat ecoregion. This area is characterized by long cold winters and short cold summers. The mean annual temperature is -6^{0}C. Since the growing season is only between 60 and 80 days long, plant life in this region consists mainly of alpine heath, sedge meadows, lichens, and both dwarf willow and birch (Bell 2002; NL Natural Resources 2007).

As with the Coastal Barrens, the Low Arctic Torngat ecoregion is a part of the Nain Geological Province. The geology of Nachvak, Komaktorvik, and Big Head consists of tonalitic and granitic gneisses and schists formed through dynamothermal metamorphism and orogenisis. These also formed between the eoarchean and the paleoarchean (4.0 to 3.2 billion years ago) (Taylor 1977; NL Geological Survey N.D.).

Considering this, and similar to the Coastal Barren region, the main mineral constituents of soils in this area are likely quartz, orthoclase feldspar, biotite, amphibole, and pyroxene, meaning that Ca, Na, Mg, Fe, Al, Si, K are the primary elemental components of these soils. Once again, this suggests that caution must be exercised when interpreting anthropogenic eutrophication of these elements in soils from the Low Arctic Torngat ecoregion. The similarities in the geological parent materials at the sites suggest that the geochemical data from them can be considered together.

Archaeological deposits in Labrador's Torngat eocregion are seasonally frozen (Fitzhugh 1980a: 601). This could slow down hydrolysis and other chemical reactions, benefiting the retention of anthropogenic chemical inputs. Permafrost in the Low Arctic Torngats occurs in discontinuous patches (Bell 2002). The soil systems encountered at Nachvak, Komaktorvik and Big Head appear cryosolic, indicated by isolated permafrost patches found in soil cores. Furthermore, the deposit at Komaktorvik has mixed sediment textures and lenses of gravel and sand, likely indicating a turbic system (CCWG 1998: 74). The deposit at Komaktorvik recorded a sequence of alternating pedogenesis and sedimentation. The cultural layers, Ahy and Bm, consist of a loamy, organic soil, interrupted by periods of sedimentation (Figure 4.2). The sediments were likely transported through aeolian action and alluvially via the river system flowing through the site. Considering the horizons present and the pH level of the soil, which is less than 5.5, this deposit appears to be of the orthic dystric turbic suborder. However, the suborder of the deposit is rather ambiguous. More research regarding the taxonomic classification of soils systems on Labrador Inuit archaeological sites is necessary.

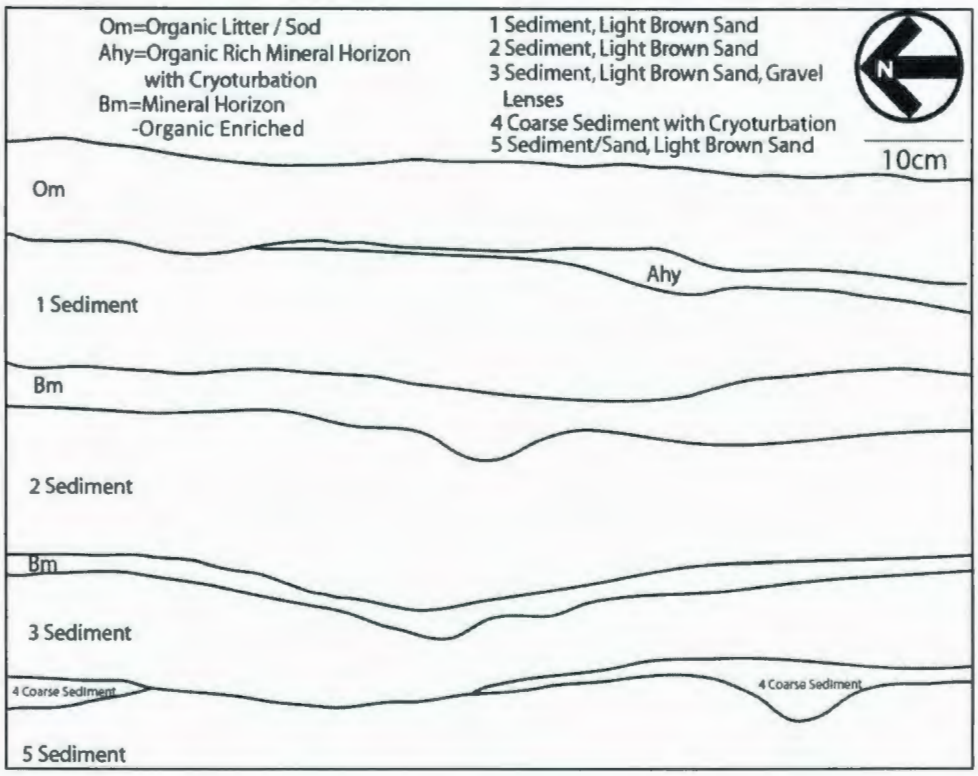


Figure 4.2: Soil Profile of the East Wall of Test Unit 03b at Komaktorvik

The soil systems in both ecoregions have characteristics that could benefit the retention of anthropogenic chemical inputs. The deposits are frozen for most of the year, hindering hydrolysis, leaching, and other types of chemical and biological processes. The deposits are somewhat poorly drained, owing to high water tables and permafrost patches. This, combined with the low annual temperature of the deposits, should slow down leaching. Additionally, Tedrow and Harries (1960: 246) state that northern tundra soils have very low leaching potentials. Most of the deposits also have high clay contents, which helps absorb anthropogenic chemical inputs, reducing their mobility within the systems (Wells 2004: 71).

As mentioned, control samples were taken several meters away from the nearest dwelling on each site, from areas with similar elevations, geology, pedology, and

vegetation. The soil characteristics identified through coring and profiling were useful for identifying similar off-site locations for control sampling. The top 5 to 10 cm of each soil column was discarded to avoid testing highly chemically active surface horizons.

Iglosiatik 1

Iglosiatik Island is approximately 50 km south of Nain in outer Voiseys Bay. Our investigations in 2007 focused on HbCh-1, an early Labrador Inuit (Thule) habitation site on the west end of the island's south coast (Figure 1.1). Located close to both the *sina* and interior terrestrial resources, it was an ideal place for an Inuit winter settlement. The site consists of 16 semi-subterranean sod dwellings built into an arc-shaped terrace, which is now overgrown with dwarf willow and birch, sedge, and lichens, perhaps indicating anthropogenic nutrient enrichment (Figures 4.3 and 4.4). The site was initially identified in 1980 during the Smithsonian's Torngat Archaeology Project (Kaplan 1983: 455, 2000: 1). From her subsequent investigations in 1993 and 1994, Kaplan (2000: 5) obtained radiocarbon dates between A.D. 1265 and 1642. During our investigations in 2007, the site was mapped using a total station, soil samples were collected from Houses 2 and 12, and test units were excavated between Houses 7 and 8, 10 and 11, and at the tunnel mouths of Houses 9 and 16 (Figure 4.4). Considering the contents of these units, including high frequencies of ground slate blades, ground nephrite drill bits, cut mica sheets, the sporadic appearance of iron and copper, and an absence of ceramics and metals, this site was likely occupied by Inuit people between the 15th and 17th centuries.

Figure 4.3: West Facing View of HbCh-1

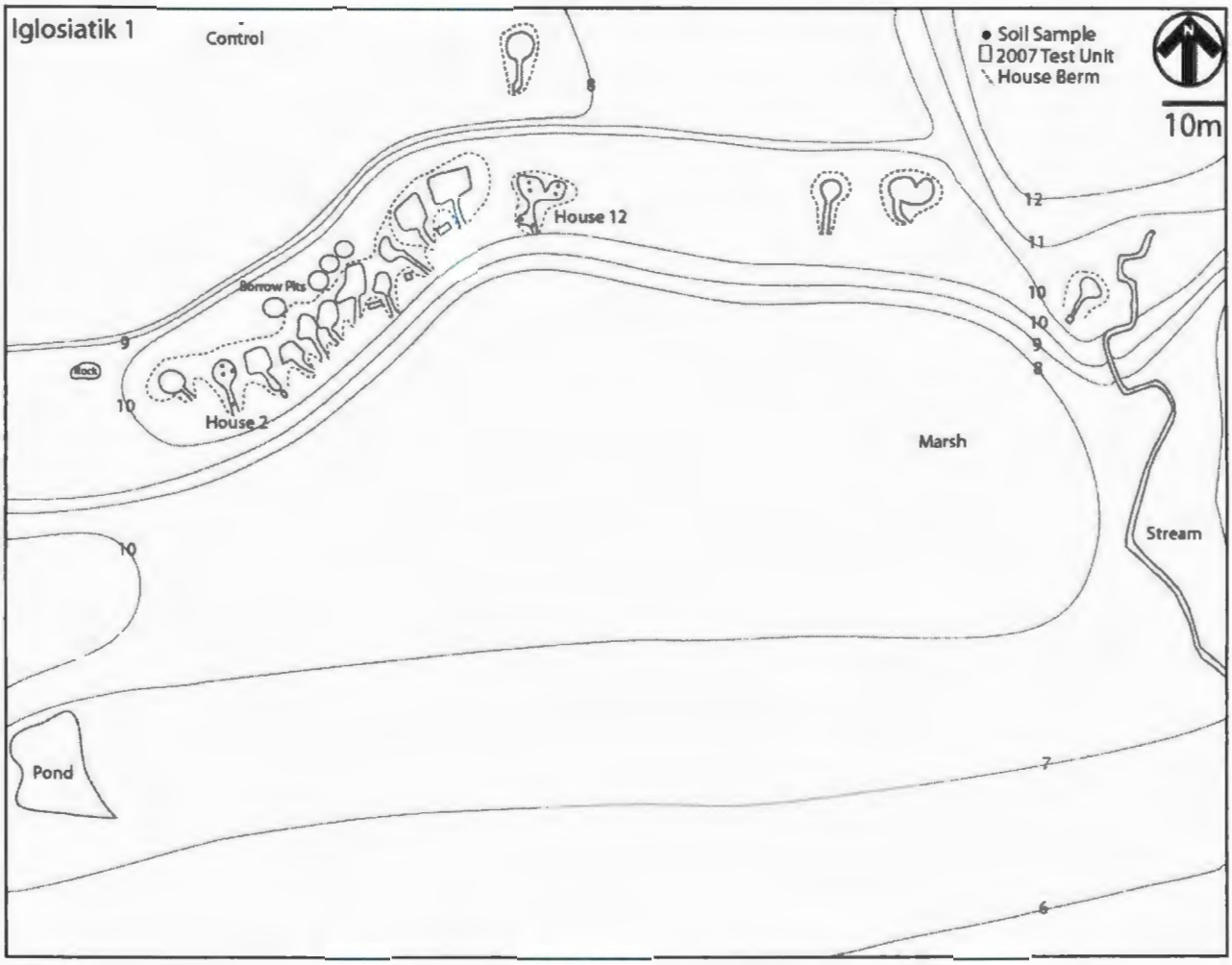


Figure 4.4: Map of Iglosiatik 1

House 2, which is near the western end of the site, was previously excavated by Kaplan (Figures 4.4, 4.5, and 4.6). Its size, shape, and interior arrangement are typical of early Labrador Inuit houses (Schledermann 1971: 68). This dwelling has an elliptical shape, an interior area of 16 m^2, and a single rear sleeping platform measuring 7 m^2. There are two storage lockers beneath the platform, indicated by upright, tabular stones that create cavities at each end of the platform. This house also has a small kitchen niche adjacent to the eastern portion of the sleeping platform that is demarcated by the upright stone slabs lining its walls. The entrance tunnel opens to the south and measures 1 m wide

by 5 m long. The lintel stone is roughly in place. During our 17 day stay, the tunnel remained flooded, indicating a high water table and poor drainage. The wall berms are well defined and shared with the adjacent houses. The walls are overgrown with willow and sedge. The platform in now covered with moss.

Figure 4.5: South Facing View of House 2

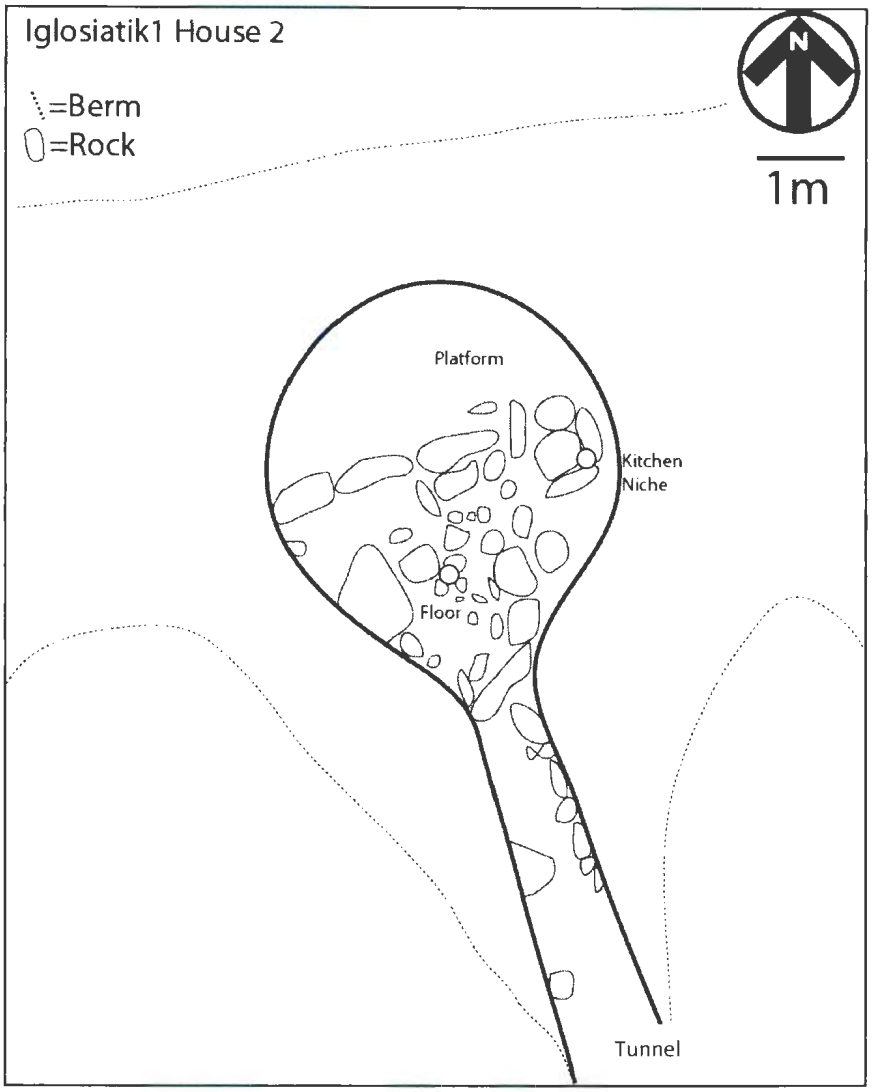


Figure 4.6: Plan of House 2

Soil columns were extracted from several locations across the floor, sleeping platform, kitchen niche (or lamp area), tunnel, and berm of House 2 (Figure 4.6). As mentioned, the samples from each respective area were combined and tested as composites. A storage area could not be identified. The floor, platform, and tunnel columns were taken at depths between 5 and 30 cm below the surface. The kitchen niche samples were taken beneath a lifted flagstone from between 5 and 20 cm below the

surface. The berm samples were cored from between 10 and 60 cm below the surface. The textures of all of the samples from House 2 are sandy clay loams. Additionally, the samples were saturated when extracted, indicating a poorly drained deposit. The samples from the floor, kitchen, niche and tunnel soils are very dark brown (10YR 2/2). The colour of the representative platform sample is dark brown (7.5YR 3/2), which is similar to the other samples. Results for the geochemical analyses of these soils are reported in Tables A.1 to A.4.

House 12 is near the middle of the house row (Figure 4.4). It has a bilobate form, which was also common in early Labrador Inuit architecture (Whitridge 2004a: 20-22). The west lobe's interior covers 18 m^2 and has a well defined rear sleeping platform measuring 4 m^2. It has a fairly continuous cover of low-growing willow. There is a small passage joining the two rooms along the south wall measuring approximately 1 m wide. The east lobe is much smaller, measuring only 8 m^2. It has a poorly defined rear sleeping platform measuring approximately 3 m^2. The size of this compartment could be the product of slumping walls. This lobe also has a rather large overgrowth of willow isolated in its southern portion. The entrance tunnel, which opens to the south, measures 1 m wide, 5 m long, and has a 3 m^2 alcove protruding from its west side that is heavily overgrown with willow. The rear berm is also overgrown with willow (Figures 4.7 and 4.8).

Figure 4.7: Southeast Facing View of House 12

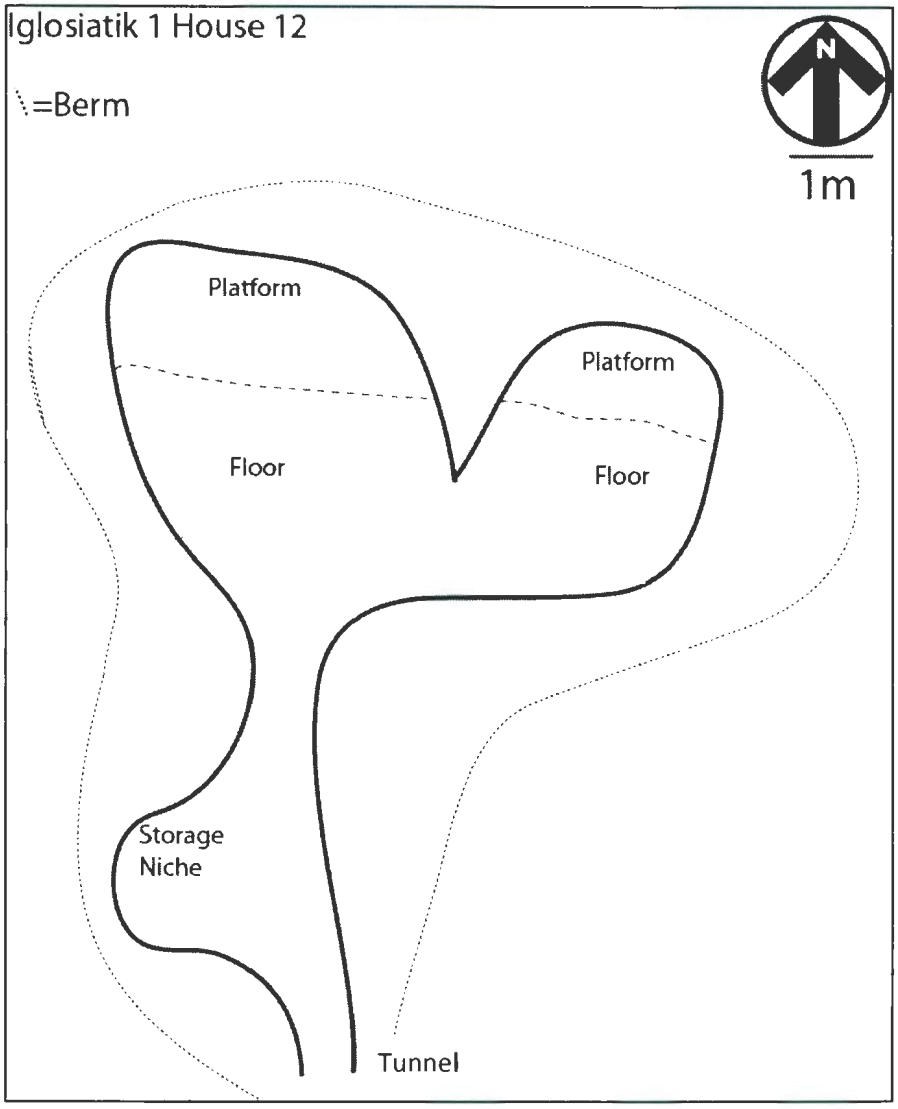


Figure 4.8: Plan of House 12

Several soil columns were taken from the floors and sleeping platforms of both lobes, the entrance tunnel, and the tunnel alcove (Figure 4.8). The berm was not tested because of interruptions in coring by stones. Additionally, lamp areas could not be identified, and were thus not tested. Soil columns from the interior of this dwelling were relatively shallow likely because the paved flagstone floors were intact and close to the surface. The floor and platform samples from the west lobe were taken from

approximately 5 to 13 cm below the surface. The floor sample has a sandy loam texture and the platform sample has a loamy sand texture. The colours of both the floor and platform composite samples are dark brown (7.5YR 3/2). Several columns for the east lobe's floor and platform were taken from between 5 and 10 cm below the surface. These samples have a sandy clay texture, are black in colour (7.5YR 2/0), and have visible wood inclusions. The composite tunnel and alcove samples were extracted from between 5 and 13 cm below the surface. Both the tunnel and alcove samples have sandy clay loam textures and a dark brown (7.5YR 3/2) colour. The results of the geochemical analyses are reported in Tables A.5 to A.8.

The control sample at Iglosiatik was taken approximately 40 m north of the nearest feature on the site. The control area has similar vegetation to that of the houses (i.e. low-growing dwarf willow, sedge, and lichen). This column was taken at a depth between 10 and 40 cm below the surface. The texture (sandy clay loam) and colour (7.5YR 3/4; dark brown) of the control soil are similar to those of the soils cored from the houses.

Nachvak Village

Nachvak Fiord is approximately 300 km north of Nain (Figure 1.1). IgCx-3 is located on a small point on the north shore of the inner fiord. This area was an ideal location for an Inuit winter settlement, given its proximity to both a polynya and interior resources. Nachvak Village (IgCx-3) was identified and tested in 1977 by the Smithsonian-led Torngat Archaeology Project (Figure 4.9) (Whitridge 2004b: 15). Maritime Archaic and Dorset peoples were the initial inhabitants of this area, which is indicated by an abundance of chipped Ramah chert refuse and tools found in test units

associated with Houses 1 through 4 (Kaplan 1983: 680). Based on the architectural styles of the 15 well-defined dwellings on this site, and temporally sensitive items such as miniature harpoon heads, it may have been one of the first Inuit winter settlements in Labrador, being occupied mainly between approximately A.D. 1450 and 1700 (Kaplan 1980: 64; Peter Whitridge, Pers. Comm.).

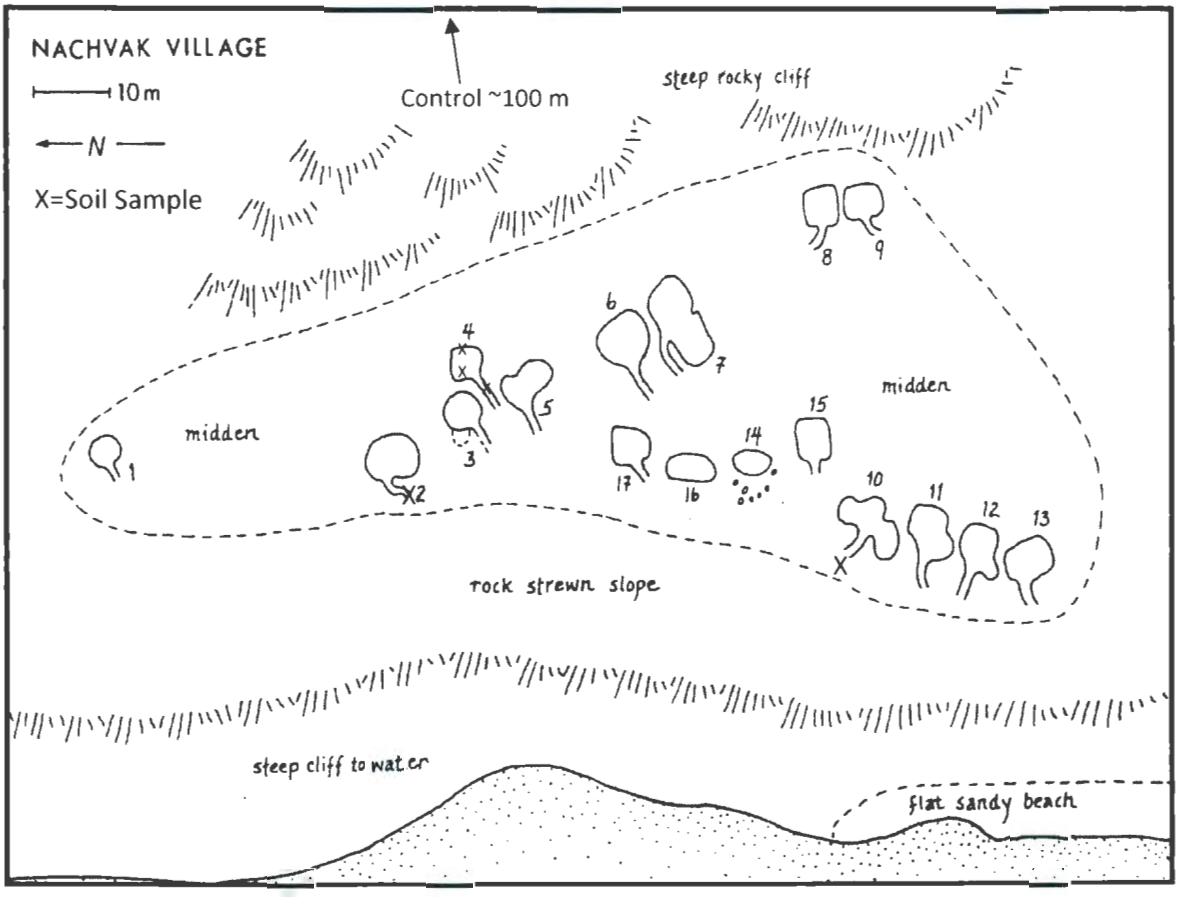


Figure 4.9: Map of Nachvak (Adapted from Kaplan 1983)

Our excavation of House 4 in 2006 produced a large assemblage of ground slate and nephrite blades, nephrite drill bits, and seal and caribou remains. The interior of this elliptical-shaped house covers approximately 16 m^2 and has a well defined, flagstone paved floor. The rear platform measures about 7 m^2 and its edge is defined by four large,

flat stones that basically bisect the dwelling. The majority of the platform is devoid of flagstones and mainly consists of compacted sand. There is also a small lamp area in the southwest portion, which was identified by a raised stone platform associated with a large soapstone lamp. The tunnel of the dwelling could not be defined with certainty, though it appears to open toward the southeast (Figures 4.10 and 4.11). Vegetation associated with this dwelling consists of discontinuous patches of sedge and a willow patch in the northwest corner.

Figure 4.10: Southeast Facing View of House 4 During Excavation

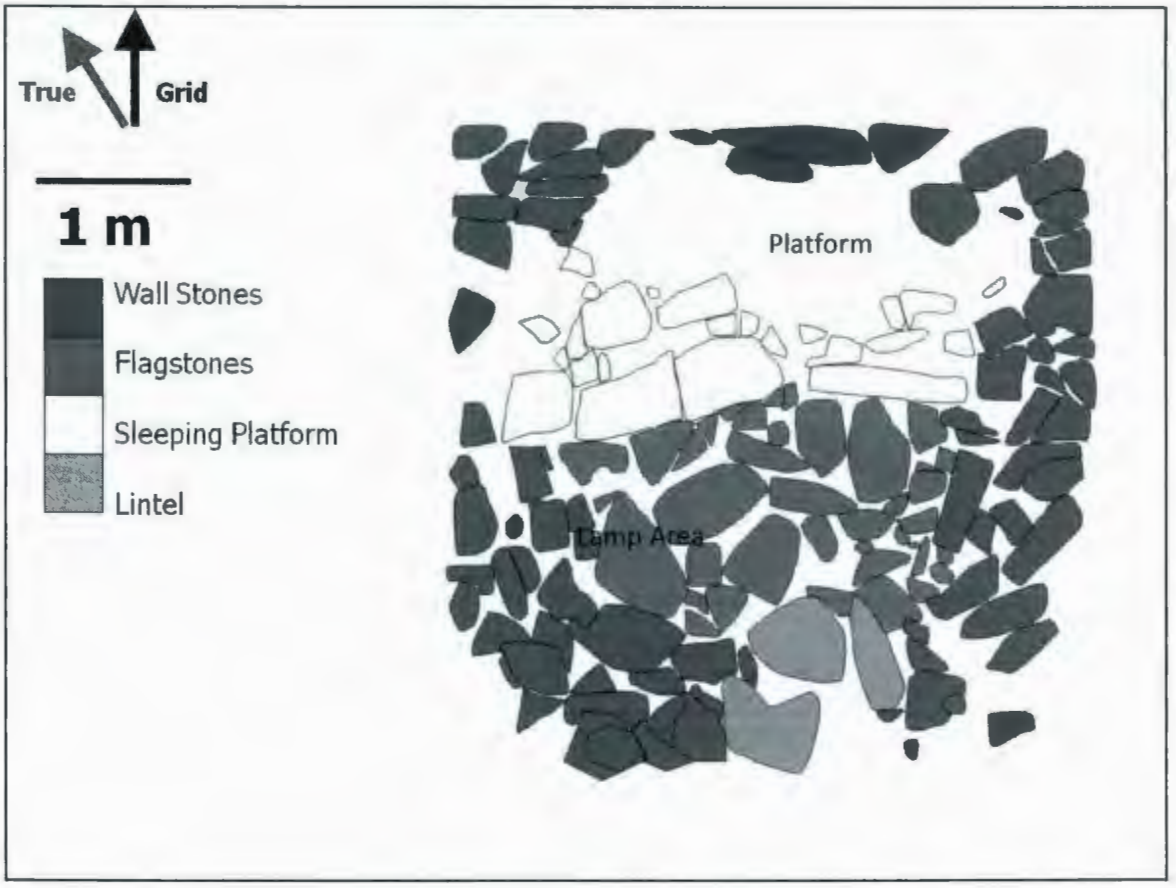


Figure 4.11: Plan of House 4's Interior

Composite soil samples were taken from middens associated with Houses 2 and 10, the platform, lamp area, and tunnel of House 4, and a control area. These samples, with the exception of the cored control, were collected with plastic tools during the excavation of their respective features. The floor and berm of House 4 were not sampled because they were disturbed by excavations before sampling could take place. The House 2 midden was sampled at a depth of approximately 30 cm below the surface and the House 10 midden at approximately 50 cm below the surface. Both midden samples are black (7.5YR 2/0) and have clay loam textures. However, soil from the midden associated with house 10 was much more organic and greasier than that of House 2. Regarding

House 4, the representative lamp area samples were collected at depths of approximately 40 cm below the surface. The composite platform samples were collected at about 30 cm below the surface (Figure 4.11). The tunnel samples were collected from approximately 40 cm below the surface. The soil samples from this house also have a consistent clay loam texture. Soil samples from the lamp and platform areas are very dark brown (10YR 2/2). The lamp area soil is also greasy and contains charred materials. The soil from the tunnel is black (2.5YR 2.5/0) and much more organic than the other samples. The geochemical characteristics of the soils collected from Nachvak Village are reported in Tables A.9 to A.12. The control sample was taken approximately 100 m north of the site from an area having discontinuous sedge and low willow cover. The texture of the control sample, which was cored from a depth between 5 and 40 cm below the surface, is the same as the on-site samples. The colour of the control soil is very dark brown (10YR 2/2).

Komaktorvik 1

Komaktorvik Fiord is Located in Seven Islands Bay, approximately 30 km north of Nachvak. Investigations in 2007 focused on IhCw-1, which is located on the outer fiord's west coast on a small sandy spit (Figure 1.1). As with the others, the location of the site provides access to both the *sina* and interior. Chipped Ramah chert debitage, endblades, bifaces, and scrapers suggest that Early Dorset people initially occupied the area. Fitzhugh (1980a: 36) notes that Early Dorset dwellings have been identified and investigated in this area. Radiocarbon dates for this component range between 2515±70 and 2110±70 B.P. (Anton 2004: 160). The Inuit component of the site consists of 13 semi-subterranean sod dwellings that are distinguishable from their surroundings by the lush grass growing around them, indicating anthropogenically derived chemical

enrichment (Figures 4.12 and 4.13) (McCartney 1979b). During our 2007 investigations, the site was mapped using a total station and test units were excavated near Houses 1, 2, 5, 9, and 11. High frequencies of ground stone tools, ceramics, and metals in these tests suggest that Inuit people occupied the area between the early 15th and early 20th centuries (Kaplan 1980: 648, 1983: 710, 741). Since various phases of Inuit occupation are present at IhCw-1, houses representing early (15th - 17th centuries), middle (18th century), and late (19th – early 20th centuries) occupations were chosen for sampling. These were Houses 9, 11, and 1 respectively.

Figure 4.12: East Facing View of Komaktorvik 1

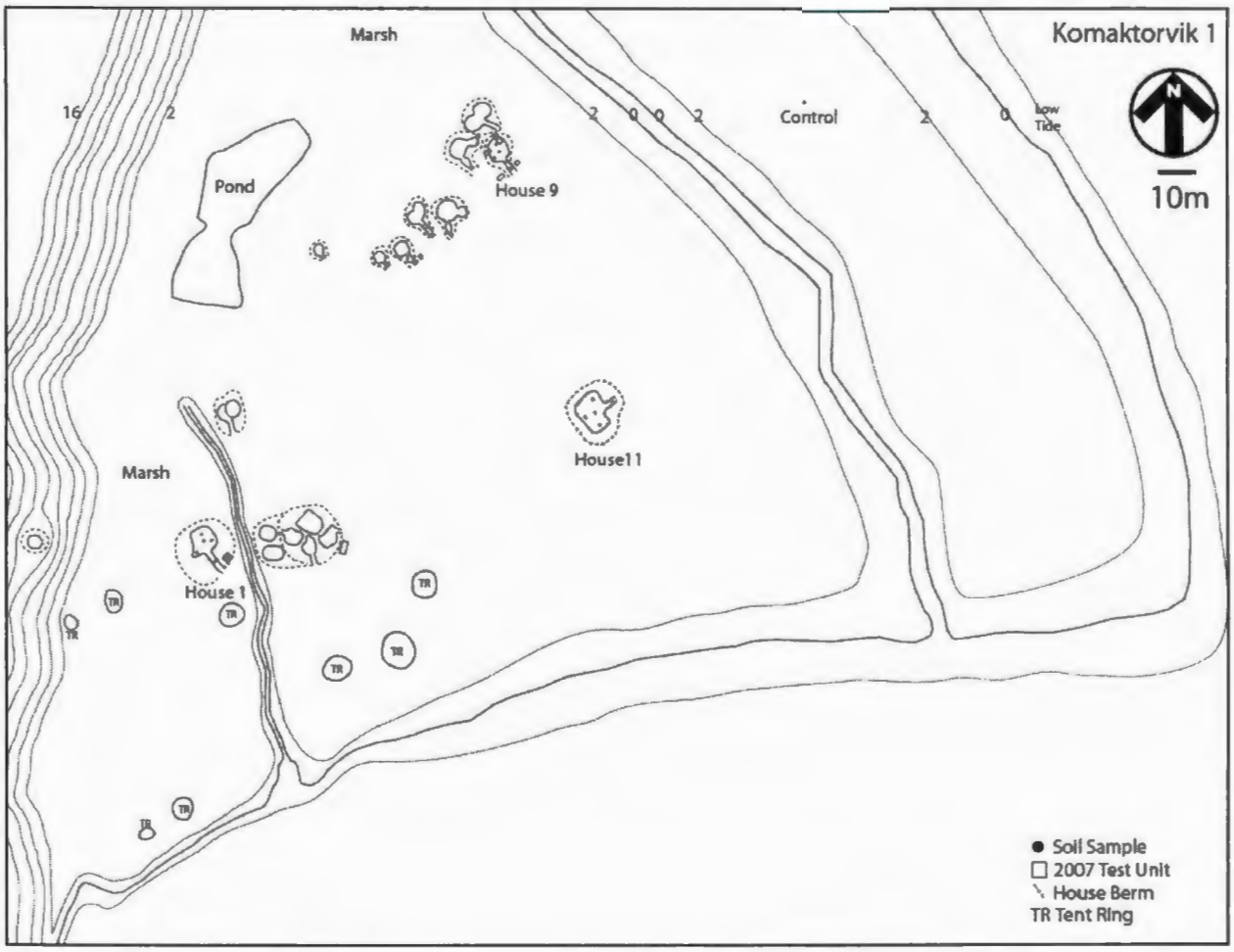


Figure 4.13: Map of Komaktorvik 1

House 9 is located at the east end of the site's most northerly house row, which consists of seven other dwellings that were likely occupied before European contact (Figures 4.13, 4.14, and 4.15). The interior and berm of this dwelling are well defined. Its elliptical shape and interior organization suggest an early Labrador Inuit occupation. The associated test units were devoid of European materials, also suggesting the dwelling was occupied during the pre-contact period. The interior has an area of approximately 28 m^2 with a 9 m^2 rear sleeping platform. There is also a lamp platform, demarcated by a raised area and a relative abundance of charred materials in the extracted soil column, along the

southwest wall adjacent to the platform. The tunnel is 1 m wide and 5 m long. The vegetation inside this dwelling consists mainly of sedge, lichens and sphagnum moss (Plate 4.6; Figure 4.9). Interestingly, a large concentration of buried baleen, which could be the remnants of a woven baleen mattress, was associated with a patch of sphagnum in the northeast corner of the platform.

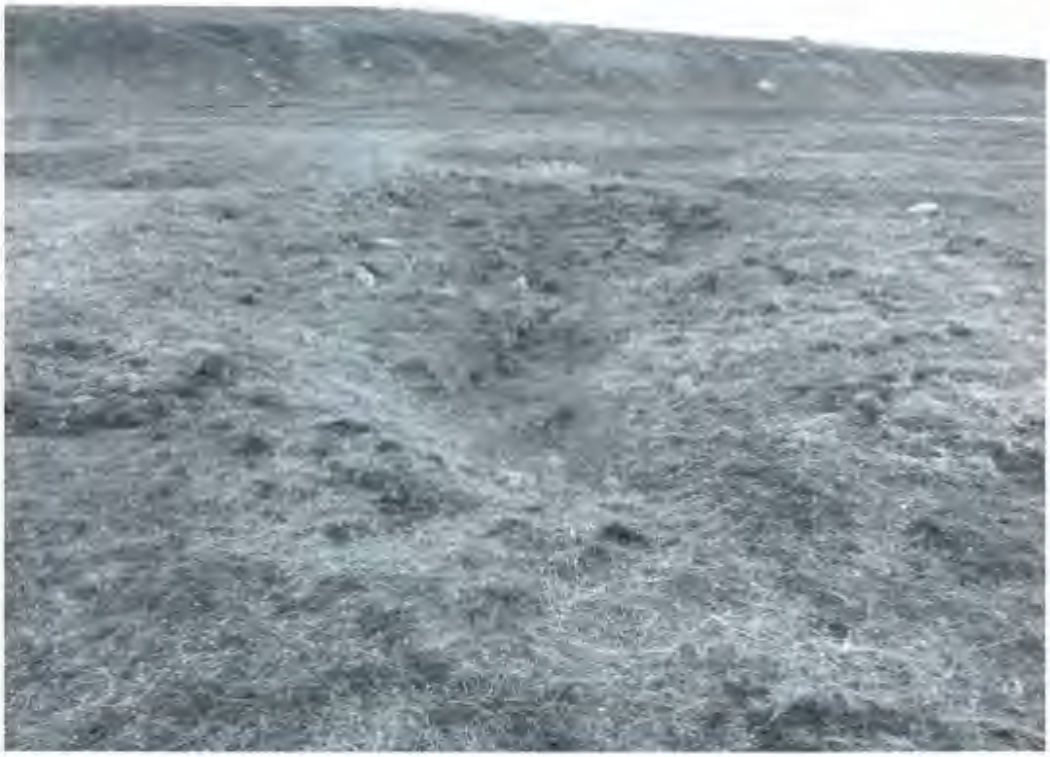


Figure 4.14: Northwest Facing View of House 9

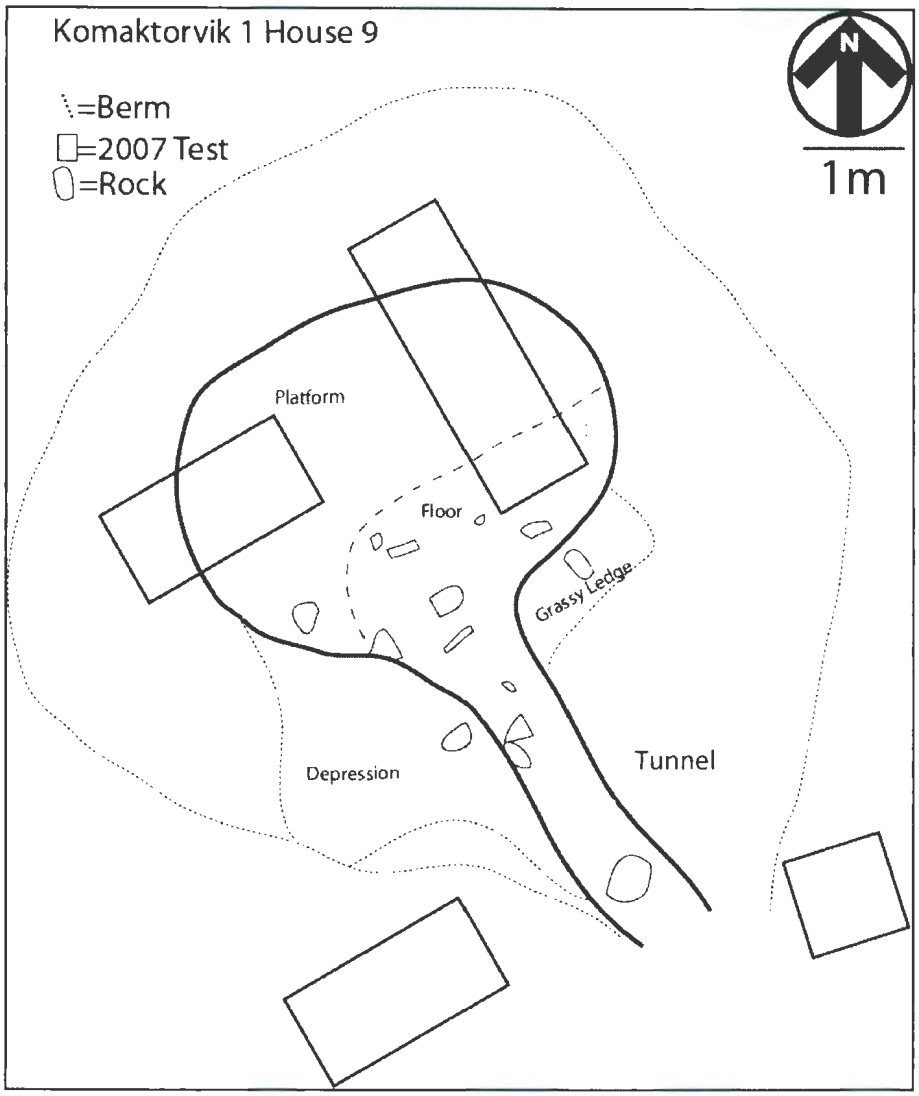


Figure 4.15: Plan of House 9

Soil samples from House 9 were recovered from several places on the floor, sleeping platform, lamp area, entrance tunnel, and wall berm (Figure 4.15). A storage area could not be identified for sampling. The floor samples were taken from between 5 and 25 cm below the surface and was interrupted by the flagstone floor. The platform, lamp area, tunnel, and berm samples were extracted from between 5 and 50 cm, 5 and 20 cm, 5 and 20 cm, and 10 and 60 cm below the surface respectively. The platform, lamp area,

tunnel, and berm samples have sandy clay textures. Though the floor sample is a sandy clay, it appears to have a higher degree of organic enrichment than the other samples from this house. The soils collected from this house all have the same very dark brown colour (10YR 2/2). The elemental concentrations, pH, Eh, and TDS of House 9's soils are reported in Tables A.13 to A.16.

House 11 is dissociated from the rest of the dwellings at IhCw-1 (Figure 4.13, 4.16, and 4.17). Its sub-quadrilateral shape, size, and sleeping platform arrangement suggest it is an 18th century communal dwelling (Kaplan and Woollett 2000: 352). This house is large, having an interior area of approximately 50 m^2. It also has three sleeping platforms: one at the rear and one on each side. The rear platform covers 9 m^2 and both side platforms measure 12 m^2 each. Interestingly, the south platform is higher than the others and has thicker, healthier grass. The entrance tunnel is 1 m wide, 4 m long, and opens northeast. The vegetation associated with this dwelling consists mainly of sedge and moss. The walls have the most and healthiest sedge. The tunnel and floor have a light cover of sedge and moss.

Figure 4.16: Southwest Facing View of House 11

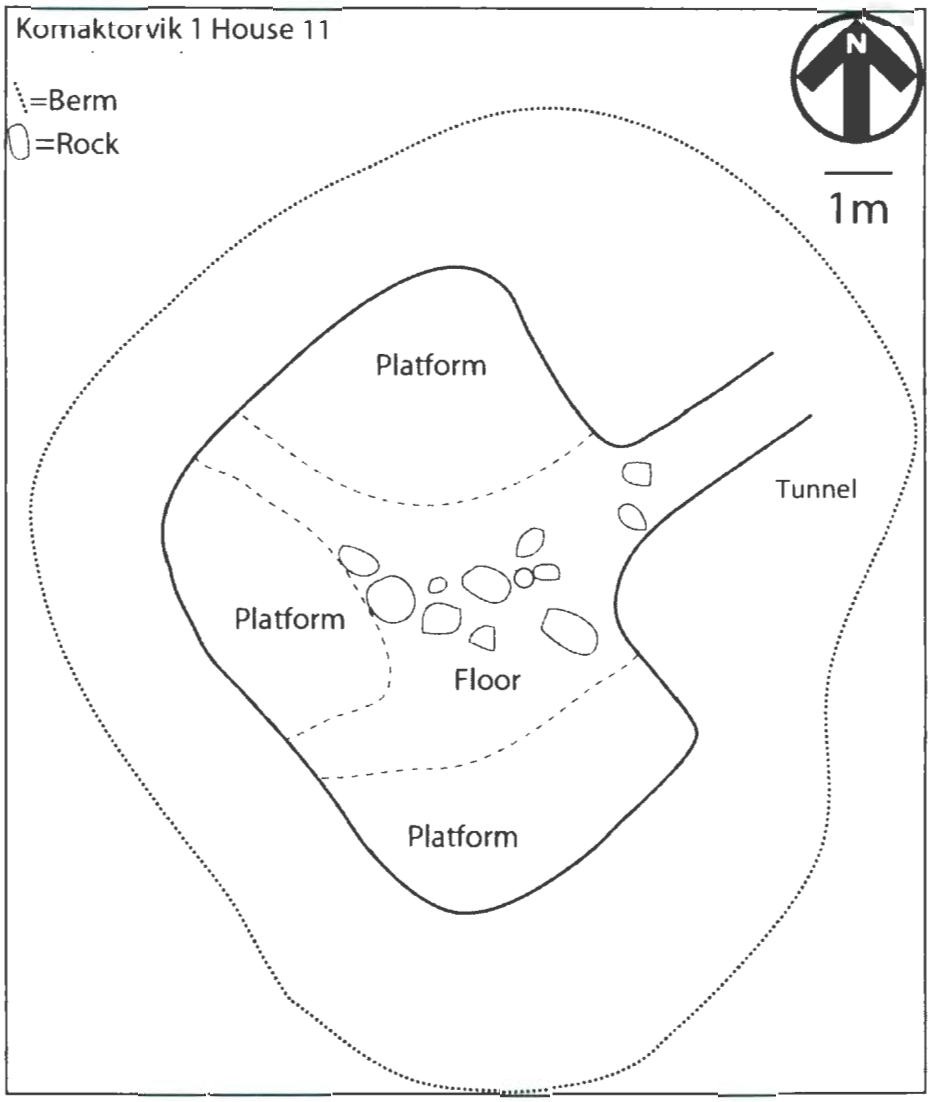


Figure 4.17: Plan of House 11

Several samples were taken from the floor, each platform and the entrance tunnel (Figure 4.17). Lamp and storage areas could not be identified. The floor sample was cored from a depth between 5 and 20 cm below the surface. These soil columns also have visible wood inclusions. Each platform was cored to depths between 5 and 30 cm below the surface. Soil samples from the south platform have visible charcoal inclusions. The tunnel columns were taken at depths between 5 and 20 cm below the surface. The textures

of the samples from this house are sandy clay loams. The floor, south platform, and tunnel have soils with a very dark brown colour (10YR 2/2), while the remaining platforms are dark brown (75.YR 3/2). The results of the geochemical analyses of these soils are reported in Tables A.17 to A.20.

Houses 1 and 2, which are located on the southwest portion of the site, represent the latest Inuit occupations at IhCw-1 (Figure 4.13). The contents of the test units associated with House 1, including banded annular wares, purple transfer printed wares, cartridge casings, rifle parts, and trapping equipment, suggest a 19th century occupation (Kaplan 1983). This house has a sub-quadrilateral shape, a total interior area of 30 m^2, and a single 9 m^2 rear sleeping platform. The lamp area is directly in front of the platform, roughly in the middle of the floor, and is demarcated by a cluster of raised, flat stones. House 1 also has a 3 m^2 alcove in its southwest corner. The entrance tunnel is 1.5 m wide, 8 m long, and opens to the southeast. This house has a very high, wide berm that is overgrown with very healthy sedge (Figures 4.18 and 4.19). A test unit excavated in the tunnel by Kaplan (1983: 710) indicates three separate occupations.

Figure 4.18: Northwest Facing View of House 1

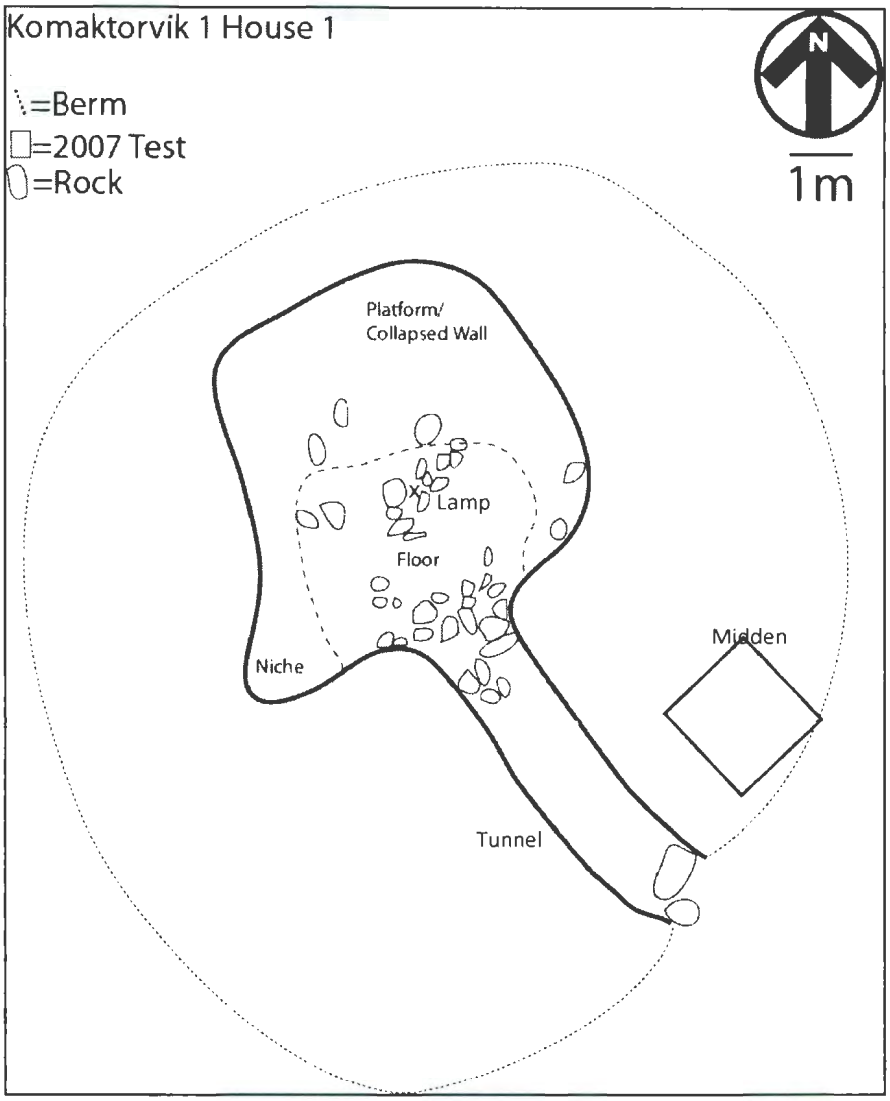


Figure 4.19: Plan of House 1

Several soil columns were removed from each visible feature of House 1, namely the floor, lamp area, sleeping platform, tunnel, and wall berm (Figure 4.19). The midden on the east side of the tunnel was also sampled. The floor samples were extracted between 5 and 25 cm below the surface. Deeper sampling in this area was not possible because of interruption by subsurface floor flagstones. Additionally, these cores struck a frozen deposit. The lamp area was cored between 5 and 30 cm below the surface. These samples

have visible bone, charcoal, and charred fat fragments. The sleeping platform was sampled between 5 and 35 cm below the surface. These samples also have visible bone fragments. The columns taken from the wall berm were rather deep, measuring between 10 and 60 cm below the surface. The soils extracted from this house are sandy, organically enriched clays. The midden samples were taken from between 5 and 50 cm below the surface, have visible traces of bone and charcoal, and greasy, sandy clay textures. The floor, platform, and midden soils are very dark brown (10YR 2/2). The composite tunnel sample is black (10YR 2/1) and the berm sample is dark reddish brown (5YR 3/2). The results of the geochemical analyses of these soils are reported in Tables A.21 to A.24.

The control area at Komaktorvik is approximately 75 m east of the nearest Inuit dwelling on the site. Vegetation is sparse in this area, consisting mainly of discontinuous patches of lichens and sedge. The core depth measured between 5 and 30 cm. The soil has a sandy clay texture, which is fairly similar to most of the soil samples collected from the archaeological site. The colour of the control soil is dark brown (7.5YR 3/2), which is also similar to the archaeological samples.

Big Head 1

Big Head is located only 6 km northwest of the Komaktorvik site at the mouth of Kangalaksiorvik Fiord (Figure 1.1). The site has 10 semi-subterranean houses built mainly into a large mound, now overgrown with very lush grass (Figures 4.20 and 4.21). The small assemblage recovered from three test units placed in 2007, including iron and ceramic fragments, suggests a 19th Inuit century occupation. However, Kaplan (1983: 750) also identified both Dorset and Thule components on this site. Based on faunal

assemblages and the remnants of trapping equipment at both Big Head and Komaktorvik. Kaplan (1980: 653) suggests that during the 19th century, the Labrador Inuit people who lived in these houses practiced a trapping economy encouraged by the Hudson's Bay Company.

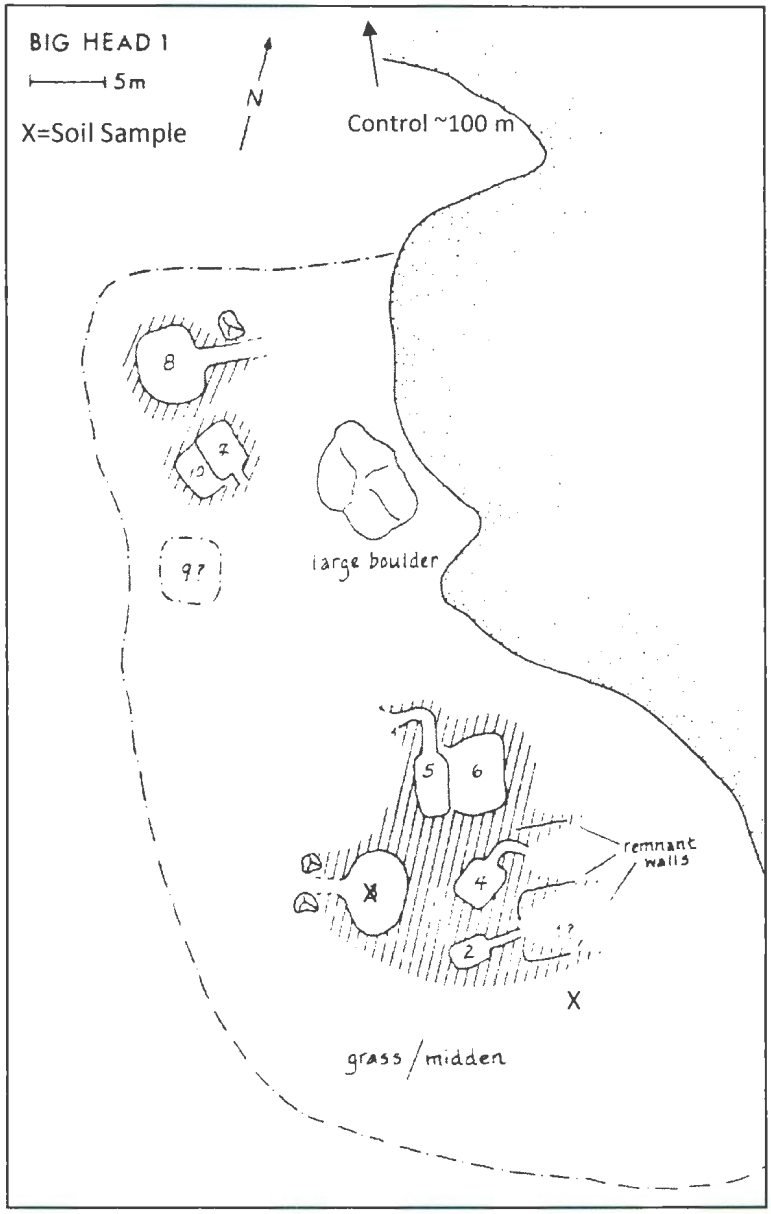


Figure 4.20: Map of Big Head (Adapted from Kaplan 1983)

Figure 4.21: Northwest Facing View of the Large House Mound at Big Head

Given that less than a day was spent investigating this site, only the floor of House 3, a nearby midden, and a control area were sampled (Figures 4.20 and 4.21). Kaplan (1983: 750) describes House 3 as an ovoid structure measuring approximately 5 m wide and 3 m long. A test unit excavated in the tunnel indicates three separate occupations occurring between the initial Thule occupation of Labrador and the early 20th century. The house also has an extreme overgrowth of tall grass. The house floor was cored between 5 and 50 cm below the surface. It has a highly organic enriched, sandy clay texture with visible fragments of wood and charcoal, giving it a black (10YR 2/1) colour. The midden samples were cored between 10 and 60 cm below the surface. The midden soil has a sandy clay texture, is very greasy, organically enriched, and black in colour

(2.5YR 2/0). Permafrost, charcoal, wood, and bone were also identified in this sample. The control sample, which is a black (10YR 2/1), organic, sandy clay, was taken about 100 m north of the site at a depth between 5 and 60 cm below the surface. The characteristics of the control are somewhat similar to the archaeological samples. The elemental concentrations, pH, Eh, and TDS of the soils collected from Big Head are reported in Tables A.25 to A.28.

Summary

Identifying and understanding the interior spatial organization of Thule Inuit winter dwellings over time and space are useful for distinguishing and subsequently testing such spaces in the dwellings considered here. The Thule winter dwellings described above are useful examples of how the inside of Thule Inuit houses were organized, and they are similar to those investigated for the present research, which guided my selection of sampling areas. Some aspects of the internal organization of Inuit dwellings persist, suggesting some degree of symmetry in the use of dwelling spaces over time and space. Conceivably, the behaviours that occurred inside Inuit winter dwellings were societal norms, suggesting particular household activities were likely practiced in similar dwelling places over centuries, which could leave patterned geochemical evidence in associated soil systems. Whitridge (2008) asserts that the internal organization of Inuit dwellings changes over time and space, suggesting that Inuit concepts regarding spatial organization were continually changing, and that the locations of household activities were also in flux. Considering this, soils from houses occupied during different times, and in different places, could have differing spatial patterns of eutrophication.

Thirty-eight soil samples, which are comprised of several samples across each feature, were collected from Inuit dwellings representing the 15th to 19th centuries. This range in temporality of the testing locations will help determine if similar practices were performed in similar dwelling spaces over time, reflecting the reproduction of Inuit ideas regarding the use of space over time. Two dwellings were tested at Iglosiatik, one at Nachvak, three at Komaktorvik, and one Big Head. The samples represent seven floors, nine platforms, four lamp areas, six tunnels, one tunnel alcove, three berms, four middens, and four control areas. The practices typically occurring within these dwellings that could have altered soil chemistry include cooking, tending soapstone lamps, preparing animal skins, storing food, personal grooming, manufacturing tools, and disposing of trash. The 38 samples were processed and analyzed following the procedures outlined in chapter three. Each of the control and on-site sampling locations have similar geology, pedology (e.g. colour and texture), and vegetation. Initial inspection of the geochemical data suggests that the pH and concentrations of a variety of elements have been altered within Inuit dwelling soilscapes. Considering this, Inuit archaeological deposits in northern Labrador, which generally appear cryosolic, appear to have characteristics beneficial for the retention of anthropogenic chemical inputs such as poor drainage, high clay contents, and low mean annual temperatures.

CHAPTER FIVE

STATISTICAL ANALYSES OF SOIL CHEMICAL DATA FROM FOUR INUIT SITES IN NORTHERN LABRADOR

The geochemical characteristics of the collected soil samples were identified using pH, Eh, TDS meters, XRF, and ICP-MS. Patterning in these characteristics are identified using multivariate statistics. Specifically, descriptive statistics, independent-samples t-tests, and exploratory principal components analysis (PCA) are used to understand the geochemical compositions of soils collected from Iglosiatik, Nachvak, Komaktorvik, and Big Head, northern Labrador. These statistics were generated using SPSS 16[3]. Descriptive statistics will define the distribution of the data. Comparisons of archaeological and control means using independent-samples t-tests will identify whether specific geochemical characteristics differ between habitation and adjacent non-habitation areas. Lastly, PCA will identify latent variables causing variation in soil chemical characteristics, which will help determine whether floors, sleeping platforms, lamp areas, storage areas, entrance tunnels, and middens have distinct enrichments in specific suites of these characteristics.

Descriptive Statistics

Descriptive statistics are useful for summarizing and preparing datasets for further analysis. Here, descriptive statistics serve two purposes. First, the data is tested for normality. Second, outlier cases are identified and recoded. In fact, assessing normality and identifying outlier cases are prerequisites for parametric analyses such as PCA (Leech et al. 2005: 18). The data are comprised of 38 cases (control n=4; on-site n=34) and 50

[3] The complete results of the statistical analyses are reported in Appendix B.

variables. Two variables are measured nominally, or categorically, which are the site and sampling contexts. As mentioned, the archaeological sites tested were Iglosiatik (control n=1; on-site n=11), Nachvak (control n=1; on-site n=5), Komaktorvik (control n=1; on-site n=16), and Big Head (control n=1; on-site n=2). The sampling location variable is categorized into floor, sleeping platform, lamp area, entrance tunnel, tunnel alcove, midden, berm, and control contexts. However, these areas could not be sampled from all of the houses. Some houses had no discernable lamp area, and the floor of House 4 from the Nachvak site was excavated before samples could be taken. The remaining 48 variables, which are pH, Eh, TDS, and a suite of 45 elements, are continuous, numerical variables. Since some elements were measured using both XRF and ICP-MS, the ICP-MS data will be used for the statistical analyses because they have a higher degree of analytical precision and accuracy.

The first step in this statistical analysis was to assess whether the 48 continuous variables have normal distributions (Tables B.1 and B.2). After Entwistle et al. (2000), the Kolmogorov-Smirnov statistic was used to identify whether the distributions of the soil chemical characteristics are normal. If the result of the Kolmogorov-Smirnov statistic is non-significant ($p>0.05$), the distribution is normal, producing a symmetric bell-shaped curve when plotted (Pallant 2005: 57; Babbie 2001: 189). Considering pH, Eh, and TDS, only Eh has a normal distribution. Of the 45 elements, only Na, V, Fe, Ga, Sr, Sm, Gd, Tb, Er, Lu, and Hf have normal distributions, suggesting the data should be standardized before conducting parametric analyses.

Next, skewness and kurtosis statistics were used to define the shape of the data (Tables B.3 and B.4). The skewness statistic represents the distribution's degree of

symmetry. This statistic ranges from -1 to 1, with 0 indicating perfect symmetry. A positive skew represents a clustering of values on the left end of the distribution with a longer tail on the right. Negative skewness signifies a clustering of values on the right end of the distribution with a longer tail on the left (Marques de Sá 2007: 64). Values greater than ±1 indicate an extremely skewed distribution (Leech et al. 2005: 20). Geochemical characteristics showing only a small amount of skewness (between -0.3 and +0.3) are Eh, Mg, Fe, Ca, Sr, V, Cr, Ni, Mo, Pb, and Gd. The variables with a moderate positive skew (between 0.31 and 1) are pH, K, Rb, Cs, Ba, Ti, Hf, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb, and Lu. The variables TDS, Li, P, S, Cl, Al, Mn, Cu, Zn, Zr, Nb, Y, La, Ce, Pr, Nd, Ta and Th have high positive skews (over 1). Regarding negative skewness, the elements having a moderate negative skew (between -0.31 and -1) are Na, Ga, and Sc. Specifically referring to elemental data collected from archaeological soils, Moore and Denton (1988: 27, 28) suggest that element concentrations with high positive skews have a high degree of spatial variability. They also state that the geochemical characteristics of archaeological soils often have positive skews, indicating the necessity of standardizing such data.

Kurtosis is a measure of the peakedness of the data. This statistic also ranges between -1 and +1. Zero represents a normal distribution. Positive values indicate a distribution in which most cases cluster around the center of the distribution, causing a peaked, or leptokurtic curve. Negative values signify a flat, or platykurtic distribution, meaning most cases cluster on the extreme ends of the distribution (Leech et al. 2005: 21, 22; Marques de Sá 2007: 65). Variables with slightly peaked distributions (between -0.3 and +0.3) are Nb, Ga, Hf, Gd, Yb, and Lu. Those having moderate peaks (between 0.31 and 1) are Tb, Dy, and Er. Geochemical characteristics with very peaked distributions

(over 1) are Li, P, S, Cl, Al, Mn, Zn, Zr, Mo, Pb, Y, La, Ce, Pr, Nd, Sm, Ho, Tm, Ta, and Th. The variables pH, Eh, TDS, Na, and Sc have moderately flat distributions (between -0.31 and -1). The elements K, Rb, Cs, Mg, Ca, Ba, Ti, V, Cr, Fe, Ni, Mo, Pb, and Eu have very flat distributions, meaning they have similar values across all cases, or soil sampling contexts. The results of the Kolmogorov-Smirnov, skewness, and kurtosis statistics suggest that the geochemical data collected for this study require standardization before parametric analyses are conducted.

Box and whisker plots were used to identify potential outlier values (Figures B.1 to B.9). These plots summarize distributions, providing information about the interquartile range, median, highest value, lowest value, and extreme values (outliers). The interquartile range, which is represented by the box, contains 50% of the central cases and is used to define variability and outlier cases. Outliers are values that lie further than 1.5 times the box's length from either its high or low edge (Dalgaard 2002: 65, 66; Gerber and Voelkl Finn 2005: 55, 56). In the present research, 19 potential outlier values were identified among the elements P, S, Cl, Mn, Cu, Zn, Zr, Ce, and Li. Following Pallant (2005: 178), outliers for each variable were adjusted to values slightly higher than the highest non-outlier value (Table B.5). For example, the sample from the floor of House 9 at Komaktorvik had an outlying value of 96.36 for Li. The next highest, non-outlying Li value (considering the entire dataset) was 13.18, so the outlier value was adjusted to 14.00.

Independent-Samples T-Tests

Following Griffith (1980) and Schlezinger and Howes (2000), average intensities of pH, Eh, and TDS and concentrations of the 45 elements were compared in control and

archaeological soils to determine if habitation areas are chemically distinguishable from non-habitation areas. Chemical characteristics having increases over control means in the archaeological soils could reflect human derived eutrophication. The independent-samples t-test compares average scores for two groups of cases to identify statistically significant ($p \leq 0.05$) differences between them, which is useful for testing hypotheses. Here, I hypothesize that, compared to off-site control samples, enriched chemical characteristics in archaeological soilscapes reflect human activities. Subsequently, the null hypothesis is that human activities do not influence soil chemistry.

First, the significance level of Levene's test for equality of variances, or the F statistic, was interpreted. This test determines whether the assumption of homogeneity of variance is satisfied. If this assumption is satisfied, the means for the variables in each group have similar distributions. If this value is insignificant ($p > 0.05$), equal variances are assumed and the first line of the t-test output is interpreted. Conversely, if Levene's test is significant ($p \leq 0.05$), the variances in the groups differ, violating the assumption of homogeneity of variance. However, because the groups have different distributions, a non-parametric t-value is provided. These values are found in the second row of the t-table under the category equal variances not assumed. As mentioned above, the distribution of the soil data collected from the study areas are not normally distributed, so using values obtained from the equal variances not assumed analysis is appropriate. However, not assuming equal variances provides non-parametric results, which are slightly less robust than the parametric results provided when the groups have similar distributions.

The t-value is a ratio of the mean difference between the two groups, which is obtained by dividing the numerical difference between them by their standard error. Values less than 0.05 in the 2-tailed column of the t-table indicate statistically significant differences between group means, meaning the null hypothesis can be rejected (Leech et al. 2005: 203; Fletcher and Lock 2005: 95-98; Pallant 2005: 206-208). Once statistically significant differences are identified, their mean difference and standard error should be compared to ensure that differences between groups are not likely because of chance or sampling error. Simply put, the mean difference must be greater than the standard error.

Concerning the soil's chemical reactivity, the mean pH is lower, or more acidic, on all of the tested sites. The independent-samples t-test shows that the difference in pH between on-site and control groups is significant assuming equal variances. The mean differences are also higher than the standard error, suggesting that chance or sampling error are unlikely. These results suggest the rejection of the null hypothesis, meaning the archaeological and natural soil groups are significantly different regarding pH. This suggests that the soil pH on the sites has been altered by human activities. The mean Eh is slightly higher on the archaeological sites, meaning the sites have more oxidizing soils than adjacent control areas. The floor context has the highest increase in Eh. The total dissolved solids have varying concentrations across each of the sites and sampling contexts, suggesting this measure of soil reactivity has little potential for identifying Inuit habitation areas in northern Labrador. The independent-samples t-test shows that differences in Eh and TDS between control and archaeological soils are insignificant, which supports the null hypothesis. The only measure of soil chemical reactivity

potentially useful for distinguishing Inuit habitation areas in northern Labrador is pH (Tables B.6 and B.7).

Considering means produced using elemental data from all four sites, 19 elements are enriched on all of the sites (Tables B.8 and B.9). In order of decreasing magnitude, the elements with enriched mean concentrations on the all of sites are P, S, Ti, Cs, Ce, Cl, Pb, Ta, Hf, Ba, Zn, Li, Mn, Rb, Mo, Th, K, Sr, and Eu. These elements should be useful for distinguishing Labrador Inuit archaeological sites from adjacent control areas and delimiting site boundaries. However, the independent-samples t-test shows that these on-site increases are insignificant.

Each site was also considered independently. Soils from the Iglosiatik site have increased concentrations in 32 elements (Tables B.10 and B.11). In order of decreasing magnitude, the elements Sc, Ni, Mo, Cu, S, Hf, P, Lu, Mn, Yb, Cl, Cs, Zr, Er, Ho, Tm, Tb, Fe, Y, Sm, Ga, Nb, Gd, Dy, Pr, Mg, Ti, La, Ce, Ta, Nd, and Th are increased at the Iglosiatik site. The independent-samples t-test identified that Mo, P, Lu, Cs, Tm, and Ga are significant assuming equal variances. The elements Sc, Ni, S, Hf, Mn, Yb, Cl, Zr, Er, Ho, Tb, Fe, Y, Sm, Nb, Gd, Dy, and Ti are significant not assuming equal variances. Comparisons of mean differences and standard errors identified that the differences in the concentrations of these elements between sampling groups are likely not the result of chance or sampling error. The results of this t-test supports the rejection of the null hypothesis for the elements Mo, P, Lu, Cs, Tm, Ga, Sc, Ni, S, Hf, Mn, Yb, Cl, Zr, Er, Ho, Tb, Fe, Y, Sm, Nb, Gd, Dy, and Ti. However, analytical error might be a contributing factor in the apparent increases of Sm and Zr.

The Nachvak site is considerably different, having increases in 21 elements (Tables B.12 and B.13). In order of decreasing magnitude, these are S, P, Mn, Cl, Ce, Zn, Ta, Li, Tm, Er, Ho, Yb, Dy, Tb, Hf, Pb, Lu, Ba, Gd, Th, and Eu. However, the independent-samples t-test shows that only P, Ce, and Ba have significant differences assuming equal variances. Only the elements S and Cl have significant differences not assuming equal variation. All of the elements with significant differences between the sampling groups also have mean differences higher than their respective standard errors, suggesting the observed differences are likely not because of chance or error. For the Nachvak site, the null hypothesis can be rejected for the elements P, Ce, Ba, S, and Cl.

Soils from the Komaktorvik site have increases in only 12 elements, which are, in order of decreasing magnitude, Sc, P, S, Ti, Cs, Cl, Pb, Rb, Ba, Sr, Cu, and K (Tables B.14 and B.15). Based on the independent-samples t-test, Ti is the only element with a significant increase assuming equal variances among the Komaktorvik samples. The elements Sc, P, S, Cs, Cl, Pb, Rb, Ba, and Sr have significant on-site increases not assuming equal variances. On-site enrichments for Cu and K are statistically insignificant. Regarding the elements Ti, Sc, P, S, Cs, Cl, Pb, Rb, Ba, and Sr, the independent-samples t-test indicates that the null hypothesis can be rejected, meaning that increases in these elements could reflect anthropogenic eutrophication. These elements also have mean differences higher than their respective standard errors, meaning error arising from chance is unlikely.

Soils from Big Head have increases in 17 elements (Tables B.16 and B.17). In order of decreasing magnitude, these are Zn, Cs, P, S, Ba, Cl, Rb, La, Sr, Pb, Ce, Pr, Cu, Ni, Nd, Cr, and Ti. The elements Cs, P, S, Ba, Cl, La, Pb, Ce, Pr, and Ti have significant

increases on-site assuming equal variances, suggesting rejection of the null hypothesis. This indicates that the elements Cs, S, Ba, Cl, La, Pb, Ce, Pr, and Ti could be increased because of human activities. The mean difference for each of these elements is above their respective standard errors, meaning the differences are real and likely not attributable to chance or error.

Comparisons of mean values for the 48 examined soil characteristics suggest that Inuit habitation areas and adjacent control areas are geochemically distinct. Significant pH and elemental enrichments on these sites could represent a consistent deposition of chemical by-products produced by particular, recursive spatially oriented tasks.

Exploratory Principal Components Analysis

Principal components analysis is a multivariate statistical technique useful for understanding the structure of numerical data. It groups similar variables to distinguish their affinities, which in turn helps detect structural patterns in large datasets. Considering this, PCA is useful for identifying latent processes that can help explain relationships between several geochemical characteristics in archaeological soils (Comrey and Lee 1992: 4). Since PCA effectively reduces several variables into two or three new variables, it is largely described as a multivariate ordination technique (Shennan 1997: 266-267; Fletcher and Lock 2005: 139). Although PCA will reduce the chemical data, it retains most of the information contained in the original variables (Jolliffe 2002: 63). Here, PCA will potentially identify underlying variables, or structural processes, causing variation in pH, Eh, TDS, and 45 elements within Labrador Inuit soilscapes. Essentially, the dataset, which is comprised of many variables, is simplified by combining variables contributing to structural patterns in the data and excluding those that do not (Atkinson et al. 2004:

229). Highly correlated groups of soil chemical characteristics will be linearly transformed into new, uncorrelated variables, or principal components, reducing the dimensionality of the data so they can be interpreted graphically in low-dimensional component loading plots (Dunteman 1989: 7; Baxter 2003: 73). These new variables are useful for delineating latent processes causing variation in groups of highly correlated soil characteristics. The latent processes providing the geochemical data with structure are likely related to the enactment of particular activities in socially defined spaces.

Principal components analysis is sensitive to outlier values and abnormal distributions (Tabachnick and Fidell 2001: 588). As mentioned above, the dataset is not normally distributed. Principal component analysis is also scale dependent. Simply put, the variables under analysis must be measured on the same scale to identify relationships between them. A base 10 logarithm (log(x)) was used to standardize the dataset. A constant of 1 was added to the logarithm because some elements had a 0 value (log(x+1)). Numerical datasets typically undergo this type of standardization to guarantee that each variable plays an equal part in the analysis (Shennan 1997: 299).

The standardized dataset must satisfy a set of statistical assumptions to ensure valid results. Specifically, the data are tested for sampling adequacy, multicollinearity, and sphericity. Sampling adequacy is debated among proponents of PCA. Comrey and Lee (1992) assert that a sample size of 1000 produces "excellent" results, 500 samples produce "very good" results, 300 samples will produce "good" results, but a sample size of 100 or less produces "poor" results. However, Gaudagnoli and Velicer (1988) argue that sample size is irrelevant if a component has four or more correlations, or loadings, over 0.60. Tabachnick and Fidell (2001) suggest using a case to variable ratio of 5:1,

meaning an adequate number of cases can be achieved by collecting five samples for every variable under analysis. Additionally, the Kaiser-Meyer-Olkin statistic is useful for determining if the dataset contains an adequate number of samples. Kaiser-Meyer-Olkin values between 0.50 and 0.70 are "mediocre", values between 0.70 and 0.80 are "good", and values above 0.80 are "excellent" (Kaiser 1974). Tabachnick and Fidell (2001) warn that a value of 0.60 should be used as a cut-off point for sampling adequacy. Moreover, values below 0.50 suggest that additional data collection is necessary.

The determinant statistic was used to assess multicollinearity. The determinant statistic for each correlation matrix must be greater than 0 but preferably over 0.00001 for a "good" analysis (Leech et al. 2005: 82). If the determinant is 0, multicollinearity could be a problem, meaning some variables correlate too highly. However, moderate multicollinearity should not be a problem when conducting exploratory PCA (Field 2005: 641). Each correlation matrix must also have some coefficients over 0.30 to produce reliable factors (Tabachnick and Fidell 2001). If a correlation matrix has several large coefficients (e.g. R>0.60), the variables in the matrix are related, or overlap in what they measure (Comrey and Lee 1992: 5). Bartlett's test of sphericity was used to identify identity matrices, in which variables only correlate with themselves. If this test is significant ($p<0.05$), the dataset will not produce an identity matrix, making it factorable (Pallant 2005: 178). Satisfying the Kaiser-Meyer-Olkin, determinant, and sphericity statistics ensures that the correlation matrices produced during the analysis are factorable into reliable components.

Principal components analysis produces eigenvalues, which are used explain the degree to which a given component, or group of highly correlated variables, contributes

to the total variation observed in the dataset (Dunteman 1989: 15). Once the data are factored into components, Kaiser's criterion is used to determine the importance of each component for explaining variation in the data, suggesting that eigenvalues greater than one represent a sizeable amount of variation and contribute significantly to the structure of the dataset. Components with eigenvalues over one were retained for further analysis. Eigenvalues less than one explain less variation, contain less information, and were typically discarded. However, strictly adhering to Kaiser's criterion can lead to the rejection of relatively small but important components (Dunteman 1989: 22). Jolliffe (1972) suggests Kaiser's criterion is too rigid because sampling error can produce components with eigenvalues less than one, so retaining components with minimum eigenvalues of 0.70 is a more useful method. Plots of eigenvalues, called screeplots, are also useful for determining how many components to extract (Dunteman 1989: 22). When eigenvalues are plotted in increasing order, the most important components lie beyond the point of inflexion, which is the point on the plot where eigenvalues suddenly increase, producing a steep slope (Comrey and Lee 1992: 107). However, Reyment et al. (1993: 206) suggest the number of components retained for analysis should be based on the cumulative amount of variance they explain. One should aim to account for between 95 and 99% of the variation in the data. This may require retaining a large number of components. Ideally, two or three principal components will be extracted to explain variation in the geochemical dataset collected from Iglosiatik, Nachvak, Komaktorvik, and Big Head in northern Labrador.

The extracted components will be rotated to interpret their latent meanings. Component rotation simplifies variable loadings, projecting components to maximize

differences between them (Jolliffe 2002: 269). Rotating the component loadings of extracted latent variables produces a more direct and easily interpretable summary of the variation they cause (Shennan 1997: 301). Orthogonal varimax rotation is the most common type used in archaeology (Baxter 2003: 81). This rotation shifts the coordinate axes perpendicular to their original position. This maximizes the sums of the variances of the squared loadings for each variable, creating components containing mostly large correlation coefficients. Ideally, variables will load onto mutually exclusive components (Dunteman 1989: 49). Rotating component loadings clarifies the component on which each variable is loaded by reducing tendencies for cross-loading, which is when a variable is related to more than one component (Field 2005: 644). Although rotated loadings provide a unique graphical representation of the data, they are the mathematical equivalents of the unrotated matrices (Comrey and Lee 1992: 10).

After principal components are extracted and rotated, the underlying variables they represent, which are the processes providing the dataset with structure, were identified. This is referred to as component reification (Jolliffe 2002: 269). Component reification can be accomplished by considering simple similarities and differences between a few highly loaded variables (Shennan 1997: 300; Atkinson et al. 2004: 235; Field 2004: 659). The extracted principal components underwent reification using the logged means of highly loaded variables. Specifically, I considered similarities and differences in control and dwelling context means for the variables.

Initially, a single PCA was conducted using the 45 elements. The correlation matrix has a determinant value of 0.00, meaning multicollinearity could have produced spurious components. Interestingly, however, five principal components have eigenvalues

over one. Two additional components have eigenvalues very close to one and explain a significant portion of the variance in the data. Together these seven components explain 91.6% of the variation in the dataset, suggesting seven latent processes are providing this chemical data with structure. Given the large number of variables and relatively small number of cases considered in this study, variables were also grouped (elemental groupings are based on periodicity) and analyzed separately (Table 5.1). I adhered to a 5:1 case to variable sampling ratio as closely as possible.

Table 5.1: Groups of Variables For Independent PCA

Group	Sub-Group	Category	Variables
1	---	All Elements	All Elements
2	---	Chemical Reactivity	pH, Eh, TDS
3	---	Alkali Metals	Li, Na, K, Rb, Cs
4	---	Alkaline Earth Metals	Mg, Ca, Sr, Ba
5	---	Non-Metals	P, S, Cl
6	A	Transition/Heavy Metals	Ti, V, Cr, Mn, Fe, Ni, Cu
	B	Transition/Heavy Metals	Zn, Zr, Nb, Mo, Pb, Ga, Hf
7	A	Rare Earth Elements	Sc, Y, La, Ce, Pr, Nd
	B	Rare Earth Elements	Sm, Eu, Gd, Tb, Ho, Er
	C	Rare Earth Elements	Dy, Tm, Yb, Lu, Ta, Th

The correlation matrix produced by the variables pH, Eh, and TDS is factorable because all of its coefficients are over 0.30 (Table B.18). All of the correlations between these variables are also significant. The determinant statistic of the matrix, which is 0.471, implies that the variables included in the analysis do not correlate too highly, meaning multicollinearity is not likely. The Kaiser-Meyer-Olkin (0.627) statistic shows that the data set has a "mediocre" number of cases. Bartlett's test is also significant (p=0.00), suggesting the matrix is not an identity matrix. Considered together, these preliminary statistics suggest that accurate components can be extracted from the correlation matrix. The initial solution has only one component with an eigenvalue over one. However, the screeplot shows that a second component accounts for a significant

portion of the variation in pH, Eh, and TDS values (Figure B.10). As such, I retained two components for analysis. These components explain a cumulative 88.2% of the variance in the structure of the dataset. Component one accounts for 65.5% of the variation and component two accounts for 22.7%. These components were extracted, rotated, and interpreted (Table 5.2).

Table 5.2: Total Variance Explained for pH, Eh, and TDS

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.966	65.549	65.549	1.966	65.549	65.549
2	0.682	22.730	88.280			
3	0.352	11.720	100.000			

The latent variables providing pH, Eh, and TDS with structure were identified through a comparison of mean concentrations across control and archaeological samples. Component one, which has a high inverse loading for pH and a high positive loading for Eh, represents soil characteristics with increases over control means in all dwelling contexts. Because pH has a high negative loading, it has decreases across all of the tested archaeological contexts. When rotated, component one, which represents on-site increases, explains 53% of the total variation in pH and Eh. Component two, having a high positive loading for TDS and a small positive cross-loading for Eh, represents characteristics having their highest means in the tunnel alcove context. The cross-loading for Eh suggests that it is typically increased on Inuit sites, and has particularly high increases in the tunnel alcove. This rotated component explains 35% of the variation in TDS and Eh (Table 5.3, Figure B.11, and Figure B.25).

Table 5.3: Component Matrices for pH, Eh, and TDS

	Unrotated Component
	1
LOGEh	0.876
LOGpH	-0.836
LOGTDS	0.707

1 component extracted.

	Rotated Components	
	1	2
LOGpH	-0.915	
LOGEh	0.841	0.313
LOGTDS		0.972

Rotation converged in 3 iterations.

The alkali metals Li, Na, K, Rb, and Cs produced a matrix with 11 correlations over 0.30 (Table B.19). The majority of the correlations in the matrix are significant. Multicollinearity is not a problem because the determinant statistic (0.002) is higher than 0.00001. The Kaiser-Meyer-Olkin statistic (0.648) signifies a "mediocre" amount of cases. Bartlett's test is also significant (p=0.00), meaning the variables correlate moderately, avoiding the problems associated with identity matrices. Together, the correlations over 0.30, the determinant value, and Bartlett's test imply that the correlation matrix will produce accurate principal components. Eigenvalues and the screeplot indicate that two components account for most of the variation in the concentrations of Li, Na, K, Rb, and Cs (Figure B.12). Component one accounts for 66.7% of the variation and component to accounts for 22.1%. A total of 88.8% of the variation in concentrations of Li, Na, K, Rb, and Cs is accounted for (Table 5.4).

Table 5.4: Total Variance Explained for Li, Na, K, Rb, and Cs

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.338	66.754	66.754	3.338	66.754	66.754
2	1.106	22.116	88.871	1.106	22.116	88.871
3	0.474	9.481	98.352			
4	0.066	1.319	99.671			
5	0.016	0.329	100.000			

The rotated and unrotated loading matrices are similar. Component one has high positive loadings for K, Rb, Cs, and Na, though Na is cross-loaded. When compared to the control samples, these elements have increases in several of the archaeological soils. In particular, they have their highest mean concentrations in the tunnel alcove. This rotated component explains 65.9% of the variation in K, Rb, Cs, and Na concentrations. Component two has a high positive loading for Li and a small cross-loading for Na. The element Li has its highest mean concentration in the sleeping platform context. The highest and second highest means for Na are found in the alcove and platform contexts respectively. This suggests that high increases in Na are typically associated with storage areas and sleeping platforms in Labrador Inuit winter dwellings (Table 5.5, Figure B.13, and Figure B.26). After rotation, component two explains 22.8% of the variation in Li and Na.

Table 5.5: Component Matrices for Li, Na, K, Rb, and Cs

	Unrotated Components	
	1	2
LOGK	0.992	
LOGRb	0.972	
LOGCs	0.863	
LOGNa	0.808	0.340
LOGLi		0.958

2 components extracted.

	Rotated Components	
	1	2
LOGK	0.989	
LOGRb	0.983	
LOGCs	0.884	
LOGNa	0.757	0.443
LOGLi		0.964

Rotation converged in 3 iterations.

The alkaline earth metals Mg, Ca, Sr, and Ba are also factorable. Their correlation matrix has eight values greater than 0.30 (Table B.20). Only two correlations in the matrix are insignificant. The determinant value is 0.037, which is well above the cut-off value of 0.00001. As such, the variables do not correlate too highly. The Kaiser-Meyer-Olkin test (0.634) suggests the analysis has a "mediocre" amount of cases. Given that

Bartlett's test is significant (p=0.00), the matrix is not an identity matrix, meaning it should generate statistically sound components. Only the first component has an eigenvalue over one. However, the second component has an eigenvalue very close to one, and the screeplot illustrates that it lies past the point of inflexion, suggesting it should be retained for further analysis (Figure B.14). The first and second components account for 70.2% and 23.6% of the variation in concentrations of Mg, Ca, Sr, and Ba respectively. These two components account for a cumulative 93.9% of the variation in the concentrations of Mg, Ca, Sr, and Ba (Table 5.6). Principal components one and two underwent extraction and rotation.

Table 5.6: Total Variance Explained for Mg, Ca, Sr, and Ba

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.810	70.262	70.262	2.810	70.262	70.262
2	0.948	23.698	93.961			
3	0.149	3.731	97.691			
4	0.092	2.309	100.000			

The rotated component loading matrix is easily interpretable (Table 5.7). Component one has high positive loadings for the elements Mg and Ca. It also has a high negative loading for Ba, though Ba has a positive cross-loading. Considering mean concentrations for Mg and Ca, component one represents elements that are not increased on the tested sites. Regarding component two, the high positive loading for Sr, the moderate positive loading for Ba, and comparisons of mean concentrations suggest that this component represents elements having increases in storage areas, middens, and tunnels. Additionally, Ba is enriched only in the tunnel alcove, explaining its cross-

loading (Figures B.15 and B.27). In the rotated solution, component one accounts for 62.8% of the variation and component two accounts for 31.1%.

Table 5.7: Component Matrices for Mg, Ca, Sr, and Ba

	Unrotated Component
	1
LOGBa	-0.960
LOGCa	0.920
LOGMg	0.891
LOGSr	-0.497

1 component extracted.

	Rotated Components	
	1	2
LOGMg	0.961	
LOGCa	0.942	
LOGBa	-0.830	0.500
LOGSr		0.988

Rotation converged in 3 iterations.

Next, the non-metals P, S, and Cl underwent PCA. All of the correlations documented in the matrix are over 0.30 (Table B.21). Moreover, all of the correlations are significant. The determinant value, which is 0.060, is well above the minimum requirement of 0.00001, so multicollinearity should not influence this analysis. A Kaiser-Meyer-Olkin value of 0.720 indicates a "good" number of cases. Bartlett's test, which is significant (p=0.00), demonstrates that the elements in the matrix correlate moderately, meaning the matrix is not an identity matrix and should produce statistically sound principal components. Eigenvalues and the screeplot both verify that most of the variation (88.5%) in the concentrations of P, S, and Cl is explained by one component (Table 5.8 and Figure B.16). Considering this, a rotated solution cannot be produced. However, rotation is not necessary because the initial solution is easily interpretable (Table 5.9). Comparisons of mean concentrations show that P, S, and Cl have their highest on-site enrichments in midden contexts (Figure B.28).

Table 5.8: Total Variance Explained for P, S, and Cl

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.657	88.571	88.571	2.657	88.571	88.571
2	0.254	8.466	97.037			
3	0.089	2.963	100.000			

Table 5.9: Component Matrix for P, S, and Cl

	Unrotated Component
	1
LOGS	0.966
LOGCl	0.945
LOGP	0.912

1 component extracted.

As mentioned, two groups of transition/heavy metals also underwent PCA. These groups were Ti, V, Cr, Mn, Fe, Ni, and Cu and Zn, Zr, Nb, Mo, Pb, Ga, and Hf. The elements Ti, V, Cr, Mn, Fe, Ni, and Cu produced a correlation matrix with 37 values over 0.30, meaning the matrix is eligible for principal component extraction (Table B.22). The determinant statistic (0.0000149) is greater than the required minimum of 0.00001. This signifies that that the variables included in this analysis do not correlate too highly, thus avoiding multicollinearity. A Kaiser-Meyer-Olkin value of 0.862 indicates that the analysis contains an "excellent" amount of cases. Bartlett's test is also significant (p=0.00), meaning the elements included in the analysis correlate moderately. Given that the correlation matrix passed the requisite statistical assumptions, it should produce components useful for understanding the underlying variables causing variation in the concentrations of Ti, V, Cr, Mn, Fe, Ni, and Cu. Eigenvalues suggest that only the first component should be retained for further analysis (Table 5.10). However, the screeplot

shows that two components lie past the point of inflexion (Figure B.17). Considering this, I decided to extract two components. The first component accounts for 79.8% of the variation and component two explains 12.8% (Table 5.10).

Table 5.10: Total Variance Explained for Ti, V, Cr, Mn, Fe, Ni, and Cu

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.587	79.815	79.815	5.587	79.815	79.815
2	0.900	12.863	92.678			
3	0.198	2.834	95.512			
4	0.173	2.477	97.988			
5	0.061	0.867	98.856			
6	0.054	0.767	99.623			
7	0.026	0.377	100.000			

The varimax rotated loading plot did not produce any cross-loadings (Table 5.11). The elements Cr, V, Ni, Fe and Cu have high positive loadings on component one. This component also has a high negative loading for Ti. Comparing the on-site and control means demonstrates that positively loaded elements on component one have their highest mean concentrations in soils associated with middens contexts. The element Ti, however, has its highest mean concentration in the tunnel alcove. The only element loaded on the second component is Mn, which has its highest mean concentration in the tunnel context (Figures B.18 and B.29). When rotated, component one explains 75.8% of the variation in concentrations of Ti, V, Cr, Mn, Fe, Ni, and Cu, while component two explains 16.8% of the variation.

Table 5.11: Component Matrices for Ti, V, Cr, Mn, Fe, Ni, and Cu

	Unrotated Component
	1
LOGV	0.975
LOGTi	-0.967
LOGCr	0.960
LOGFe	0.958
LOGNi	0.930
LOGCu	0.918
LOGMn	0.392

1 component extracted

	Rotated Components	
	1	2
LOGCr	0.969	
LOGV	0.958	
LOGTi	-0.949	
LOGNi	0.941	
LOGFe	0.914	
LOGCu	0.899	
LOGMn		0.984

Rotation converged in 3 iterations.

The second group of transition/heavy metals, which was Zn, Zr, Nb, Mo, Pb, Ga, and Hf, produced a correlation matrix containing 34 values over 0.30 (Table B.23). Most of the correlations are significant. The matrix has a determinant value of 0.015, which is greater than the required minimum of 0.00001, meaning multicollinearity should not influence the analysis. Kaiser-Meyer-Olkin's measure of sampling adequacy (0.768) suggests that the analysis has a "good" amount of cases. Bartlett's test of sphericity is also significant (p=0.00), indicating the elements in this analysis correlate moderately. Considering these results, reliable components can be extracted from the correlation matrix. The first two components in the initial solution explain a total of 72.5% of the variation in the concentrations of Zn, Zr, Nb, Mo, Pb, Ga, and Hf, which is signified by eigenvalues over one and the screeplot (Table 5.12 and Figure B.19). Component one accounts for 54.3% of the variance in the dataset and component two accounts for 18.2%. These components underwent extraction and rotation for further interpretation.

Table 5.12: Total Variance Explained for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.807	54.382	54.382	3.807	54.382	54.382
2	1.275	18.210	72.591	1.275	18.210	72.591
3	0.684	9.766	82.357			
4	0.562	8.032	90.389			
5	0.312	4.457	94.846			
6	0.265	3.786	98.633			
7	0.096	1.367	100.000			

Component one has high positive loadings for the metals Nd and Zr. The elements Mo and Pb have moderate loadings on this component, while Hf has a relatively low loading. The elements Ga, Mo, and Pb are cross-loaded, though they have higher loadings on component one. Comparing the mean concentrations of these elements demonstrates that they all have increases in the tunnel alcove, suggesting component one represents elements with characteristically high increases in the alcove. Component two has a high negative loading for Zn, a moderate positive loading for Hf, and low positive cross-loadings for Ga, Mo, and Pb. The element Zn has its highest mean in the midden context, while Hf, which has an inverse loading, has its lowest mean concentration in the midden. Component two could represent enriched elements associated with midden contexts (Table 5.13, Figure B.20, and Figure B.30). The components in the rotated solution explain 45.5% and 27.0% of the variance in concentrations of Zn, Zr, Nb, Mo, Pb, Ga, and Hf.

Table 5.13: Component Matrices for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

	Unrotated Components	
	1	2
LOGNb	0.892	0.335
LOGGa	0.813	
LOGMo	0.773	
LOGPb	0.764	
LOGHf	0.737	-0.307
LOGZr	0.711	0.603
LOGZn	-0.344	0.822

2 components extracted.

	Rotated Components	
	1	2
LOGNb	0.941	
LOGZr	0.916	
LOGGa	0.671	0.464
LOGMo	0.640	0.439
LOGPb	0.593	0.503
LOGZn		-0.885
LOGHf	0.489	0.631

Rotation converged in 3 iterations.

Lastly, three sets of rare earth elements underwent independent testing. Regarding Sc, Y, La, Ce, Pr, and Nd, the correlation matrix has 16 coefficients over 0.30 (Table B.24). Most of the coefficients are significant. Since the determinant statistic of the matrix (0.00005) is greater than 0.00001, most variables do not correlate too highly, thus avoiding multicollinearity. The Kaiser-Meyer-Olkin statistic is 0.720, suggesting the analysis contains a "good" amount of cases. The significance of Bartlett's test (p=0.00) confirms that the matrix is not an identity matrix. Given these results, the correlation matrix will produce suitable principal components. The explanation of variance has only one component with an eigenvalue over one. Although the eigenvalue for the second component is below one, it is relatively high. It also explains a large portion of the variation in the initial solution. The screeplot suggests that three components should be retained for further analysis (Figure B.21). Considering both the eigenvalues and the screeplot, two components are retained for further analysis. Eighty-one percent of the variation in the concentrations of Sc, Y, La, Ce, Pr, and Nd is explained by two principal components. Component one accounts for a total of 65.6% of the variation in elemental

concentrations and component two accounts for 15.9% (Table 5.14). These two components were extracted and rotated to aid reification.

Table 5.14: Total Variance Explained for Sc, Y, La, Ce, Pr, and Nd

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.939	65.651	65.651	3.939	65.651	65.651
2	0.959	15.980	81.631			
3	0.899	14.985	96.616			
4	0.169	2.812	99.428			
5	0.031	0.518	99.947			
6	0.003	0.053	100.000			

Component one has high positive loadings for La, Pr, Nd, and Ce. Comparisons of means across on-site soilscapes shows that elements loaded on component one have their highest mean values in lamp areas. The element Ce has its highest values in the tunnel and lamp contexts. Component one appears to represent lamp stands. Component two has a high positive loading for Sc and a moderate negative loading for Y. Both are inversely cross-loaded on component one. However, they have a higher loadings on component two. The element Sc, which is the only highly loaded element on this component, has high and similar mean concentrations in the tunnel alcove and midden contexts. Accordingly, the negative loading for Y on component two occurs because it has low mean concentrations in the alcove and midden contexts. As mentioned, Sc and Y are inversely cross-loaded on component one, meaning both elements could also have low means in soils associated with lamp areas (Table 5.15, Figure B.22, Figure B.31). After rotation, component one accounts for 65.6% of the total variation and component two accounts for 15.9%.

Table 5.15: Component Matrices for Sc, Y, La, Ce, Pr, and Nd

	Unrotated Component
	1
LOGLa	0.986
LOGPr	0.985
LOGNd	0.970
LOGCe	0.917
LOGY	-0.335
LOGSc	-0.319

	Rotated Components	
	1	2
LOGLa	0.986	
LOGPr	0.985	
LOGNd	0.969	
LOGCe	0.918	
LOGSc	-0.311	0.766
LOGY	-0.342	-0.595

Rotation converged in 3 iterations.

The correlation matrix for the rare earth elements Sm, Eu, Gd, Tb, Ho, and Er should produce statistically reliable principal components. In particular, the matrix has 22 correlations over 0.30, most of which are significant (Table B.25). The determinant value (0.0000115) is higher than the allowed minimum, meaning multicollinearity should not be a problem when factoring the matrix. The Kaiser-Meyer-Olkin statistic is 0.802, suggesting "excellent" sampling adequacy. Bartlett's test of sphericity is also significant (p=0.00), implying that the variables correlate moderately. Two components explain most of the variation in the rare earth elements Sm, Eu, Gd, Tb, Ho, and Er, which is suggested by eigenvalues over one and the screeplot (Table 5.16 and Figure B.23). Seventy-one percent of the variation in these rare earth elements is explained by component one. Component two accounts for a much lower 21.6% of the variation in the dataset. Both components together account for 93.0% of the variation in the concentrations of Sm, Eu, Gd, Tb, Ho, and Er. These components were extracted and rotated to identify their latent meanings.

Table 5.16: Total Variance Explained for Sm, Eu, Gd, Tb, Ho, and Er

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.286	71.428	71.428	4.286	71.428	71.428
2	1.297	21.620	93.048	1.297	21.620	93.048
3	0.331	5.513	98.561			
4	0.066	1.097	99.657			
5	0.014	0.226	99.883			
6	0.007	0.117	100.000			

Comparing logged means across control and dwelling contexts, the elements loading highly on component one (Er, Ho, Tb, and Gd) have their highest concentrations in sleeping platform contexts. Component two has high positive loadings for Eu and Sm. The element Eu has its highest mean concentration in the tunnel alcove, but it has similar maximum values in the floor, platform, lamp, and tunnel contexts. The element Sm has its highest mean in the platform context, explaining its loading on component one. It also has a high mean concentration in the tunnel context. Component two is rather ambiguous, but it could represent the tunnel context. The element Gd is also cross-loaded, but has a higher degree of association with component one, suggesting this element could be indicative of soils from platform or tunnel contexts. Its high loading on component one suggests it has a higher degree of association with platform contexts (Table 5.17, Figure B.24, and Figure B.32). The rotated components explain 71.4% and 21.6% of the variance in the dataset respectively.

Table 5.17: Component Matrix for Sm, Eu, Gd, Tb, Ho, and Er

	Unrotated Components	
	1	2
LOGTb	0.979	
LOGGd	0.973	
LOGHo	0.957	
LOGEr	0.953	
LOGSm	0.669	0.607
LOGEu	0.329	0.875

2 components extracted.

	Rotated Components	
	1	2
LOGEr	0.984	
LOGHo	0.984	
LOGTb	0.978	
LOGGd	0.920	0.319
LOGEu		0.934
LOGSm	0.408	0.806

Rotation converged in 3 iterations.

The determinant statistic of the correlation matrix produced by the rare earth elements Dy, Tm, Yb, Lu, Ta, and Th has a value of 0.00, meaning that unreliable principal components will be produced because of multicollinearity (Table B.26). However, increasing the number of cases in the dataset could remedy this problem.

Summary

This chapter discussed the statistical analyses conducted on geochemical data collected from four Inuit archaeological sites in northern Labrador. Specifically, my goal was to answer the following three research questions: 1) Do geochemical characteristics differ on archaeological sites and adjacent control areas? 2) If so, what characteristics are enriched on the sites? 3) Do house floors, sleeping platforms, lamp areas, storage areas, entrance tunnels, wall berms, and middens differ in their concentrations of these characteristics?

Kolmogorov-Smirnov, skewness, and kurtosis, indicated that logged standardization of the dataset was necessary before conducting PCA. Moreover, given that PCA is sensitive to outliers, such values were identified using box and whisker plots. Outliers were subsequently recoded. Concerning question 1, comparisons of mean values

for pH, Eh, TDS, and 45 elements indicate that habitation areas and adjacent non-habitation areas are geochemically distinct, suggesting that various Inuit activities caused eutrophication, or increases in particular chemical characteristics within the tested soil systems. Regarding question 2, the elements P, S, Cl, Cs, Ba, Ti, and Pb have significant increases on most of the tested sites, suggesting they are potentially useful for distinguishing Inuit archaeological sites from adjacent control areas in northern Labrador. The elements Sc, Ga, Nb, Lu, Tm, Mn, Fe, Ni, Y, Zr, Sm, Gd, Tb, Dy, Ho, Er, Hf, Rb, Sr, La, and Pr have significant increases in at least one sampling context, suggesting they could be useful for identifying spatially discrete activity areas. As mentioned, apparent increases in Zr, Sm, and Pr might be the product of analytical error and not human activity.

The series of PCA identified that the tunnel alcove, middens, sleeping platforms, lamp areas, and entrance tunnels have characteristically high increases in distinct suites of elements. These results answer my third research question. The analyses distinguished five different components, or structural processes, using sets of highly correlated variables. These new variables represent geochemically distinct soilscapes associated with specific activity areas on Labrador Inuit archaeological sites. The variables pH and Eh have high loadings on the component representing the tunnel alcove, but all of the sampling contexts are more acidic and more oxidizing, suggesting these variables are useful for identifying general occupation. The analyses suggest that the tunnel alcove is associated with increased concentrations of TDS, Sc, K, Rb, Cs, Na, Sr, Ba, Nb, Zr, Ga, Mo, Pb, and Hf. The element Zr, however, may not be useful for interpreting human activities in this research because of dissolution problems. Sleeping platforms have

increases in Gd, Tb, Ho, Er, Sm, and Li. Again, increases in Sm might be the product of analytical error, not human activity. Soils associated with lamp areas have increases in Ce, La, Pr, and Nd. The elements Pr and Nd, however, might not be related to human activity because of their analytical error. Soils in the entrances of winter dwellings are associated with Eu, Sm, Mn, Zn, Ba, and Sr. Middens have characteristically high increases in P, S, Cl, Sc, Cu, Fe, V, Ni, Cr, Ga, Mo, Pb, Mn, Zn, Ba, and Sr. The geochemical characteristics of soils on Inuit archaeological sites in northern Labrador appear to vary because of discrepancies in human eutrophication across the site. This suggests that different activities, which produce distinct geochemical signatures in discrete, socially defined spaces, are the latent variables providing the data with structure.

CHAPTER SIX

UNDERSTANDING CHEMICAL EUTROPHICATION ON LABRADOR INUIT ARCHAEOLOGICAL SITES

The previous chapter demonstrated that soils from different Inuit dwelling spaces have characteristically large enrichments in distinct suites of elements. This chapter identifies Inuit practices that could have caused these chemical enrichments. Over time, spatially patterned behaviours contribute chemical residues to the soils beneath Inuit dwellings, reflecting the organization of taskscapes and subsequently the reproduction of ideas regarding the use of dwelling space. Social interaction among Inuit people took place on landscapes, seascapes, icescapes, and within dwellings, generating expectations for behaviours and activities specific to those fields, or what Bourdieu (1990: 53) refers to as "...procedures to follow, paths to take...". People develop socially and contextually specific behaviours, or spatially structured dispositions, through long-term exposure to specific social and physical conditions within their dwellings. The spatial organization of household activities is a product of collective social histories, meaning Inuit people used mutual knowledge, memories, and observations of other people (which quickly become memories) when deciding how to behave in particular dwelling spaces (Bourdieu 1990; Dobres and Hoffman 1994).

Inuit people commonly occupied their winter houses between the late fall and early spring (Kaplan 1985: 49). Mauss (1906: 76) hypothesized that the spatial arrangement of these dwellings on landscapes reflects the organization of Inuit society. Taking this a step further, the organization of taskscapes within Inuit houses are patterned representations of various behaviours and social constructions. Hutton (1904: 179) claims

that "[w]inter is the social time" in Labrador Inuit society. Mauss (1906: 77, 79) also observed that winter was a time of heightened social interaction among Inuit people. During winter, then, particular types of interactions and activities occurred in both residential and ceremonial houses.

Considering these accounts, Inuit dwellings embody meaningful interactions between individuals and between people and the material conditions of their existence (Dobres and Hoffman 1994: 215). The interactions and social monitoring that occurred inside Inuit winter houses generated expectations for behaviours and activities acceptable in that field, which over time formed a set of specific dispositions, or situated subjectivities, that influenced decisions of how to use space inside these houses (Bourdieu 1990). Inuit winter houses also enabled and constrained activities (Giddens 1984). They provided a place where a hearth could be tended, where food could be prepared, consumed, and stored, and they provided a place where activities requiring light and heat could be performed such as manufacturing and repairing tools and clothes, personal grooming, and tending to infants. Inuit household practices produced liquid and particulate residues such as animal fat, charcoal, and lithic debitage that were incorporated into associated soil systems. Accordingly, the chemical by-products of Inuit activities can be measured in dwelling soilscapes as element enrichments derived from accumulations of particular liquid and particulate residues.

Chemical Eutrophication in Labrador Inuit Dwellings and Middens

Comparing concentrations between non-habitation and dwelling samples demonstrates that several elements are eutrophied within Inuit dwelling soilscapes. Independent samples t-tests also demonstrate that many of these enrichments are

statistically significant, indicating that Labrador Inuit dwellings are distinguishable from non-habitation areas based on their soil chemistry. Soils from House 2 at Iglosiatik yielded perhaps the most vivid evidence of anthropogenic eutrophication, possibly because it was previously excavated to the top of the floor. Chemical residues are expected to accumulate both on and below occupation surfaces. Given that the occupation surfaces of House 2 have been excavated and exposed, the chemical evidence that accumulated above them was likely destroyed. However, accumulations of various residues beneath the living floors, or occupation layers, became more accessible to the corer. This suggests that taking samples from both within and below occupation layers may produce more accurate and precise results. Moreover, the deposit associated with House 2 is poorly drained, conceivably slowing down eluviation, which may have contributed to the retention of the anthropogenically enriched elements.

Compared to the control area, the soils from House 2 are more acidic and oxidizing (Table A.1). The decomposition of organic matter can add H^+, N, P, S, K, and Ca to a soil system (Stein 1992: 195, 197, 199; Vizcaino and Canabate 1999: 54). For example, the decomposition of bone produces H_2SO_4. This adds H^+ to the soil deposit, making it more acidic and oxidizing. In order of decreasing magnitude, the berm, tunnel and lamp areas are the most acidic and oxidizing, suggesting the deposition of organic matter from waste disposal practices. Increases in P, K, S, Cs, and Mg in House 2 could also represent the interment of organic wastes from food production and consumption (Table A.4) (McCartney 1979b: 496, 500-502; Middleton and Price 1996: 679, 680). Bone contains approximately 20% P, which becomes incorporated into surrounding soils during its decomposition (Farswan and Nautiyal 1997: 253; Parnell et al. 2002: 392).

Increases in Rb, Ca, Ba, Sr, and Mn have been previously identified in cooking or hearth areas, meaning increases in these elements within House 2 soils are likely the products of food preparation and lamp maintenance (Entwistle et al. 2000: 296, 297; Wilson 2008: 417). These elements have varying increases throughout the House 2 soils, suggesting that wastes were scattered around the dwelling before being removed to the exterior (Table A.4). The soil associated with the kitchen niche has increased concentrations of Cs, Ba, P, and S, which could represent the interment of food remains and charred materials produced around the lamp (Table A.4). Interestingly, the lamp area has similar elemental enrichments as the floor, suggesting most wastes were initially produced around lamps and dispersed throughout the floor. If this were the case, I would expect to see more intense enrichments in the lamp area compared to the floor. However, this is generally not the case. Higher resolution sampling of floors and lamp areas would provide the data required to assess this hypothesis.

Elevated concentrations of P, K, Mg, and Mn in House 2 could represent the deposition of wood ash and charcoal (Table A.4) (Griffith 1981: 29-31; Wells 2004: 75). Potassium is increased only in the floor context, while Mg and Mn are enriched exclusively in the platform and tunnel contexts. This suggests that accumulations of charred refuse on the floor and platform were frequently swept through the tunnel. Perhaps charred materials were introduced to the platform because of its proximity to the kitchen niche. Increases in Mg, Mn, P, S, Cs, and Ca in the platform area compared to the floor could indicate that it was cleaned less often then the floor. Cleaning the platform could have involved more work, including dismantling and moving a rather large baleen mattress covered with several skins to the exterior. Removing these materials from House

2 during the winter may have been impossible, given that the tunnel is rather small, measuring 1 m wide and 5 m long.

High concentrations of the rare earth elements (Sc, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) throughout House 2 likely reflect the deposition of human detritus from general occupation (Table A.4). Cook et al. (2005: 630, 638) speculate that increases in the rare earth elements could derive from human detritus such as shed hair, skin, and fingernails. Hair and fingernails are composed of the protein keratin, which could be the source of the enrichments in these rare earth elements. Additionally, Cook et al. (2005: 634) state that rare earth enrichments between 10% and 20% are minor. The rare earth elements in House 2 are increased between 1% and 69%, indicating both minor and major departures from the control sample. The tunnel has the highest concentrations of the rare earth elements, which could indicate that wastes produced within the dwelling were swept through the tunnel to the outside of the dwelling. Borlase (1993: 90) states that dogs were often kept in tunnels, meaning rare earth enrichments in soils from tunnels could also reflect the deposition of shed dog hair. The platform also has large enrichments in the rare earths, suggesting people spent a lot of time on the platform, preparing and consuming food, making tools, and, of course, sleeping, causing a greater accumulation of keratinous human detritus in this area. Baleen, however, also consists of keratin, which is a combination of several amino acids. The most abundant amino acids in keratin are glycine and cysteine. Cysteine, in particular, contains a large amount of S. During the decomposition of baleen, cysteine could contribute S to soils associated with sleeping platforms and middens (Cronyn 1990: 282). In the platform area, S has a 127% increase

over the control sample, suggesting a baleen mattress was used in this house (Table A.4). It must also be determined whether sea and land mammal keratin are distinct or similar.

Increased concentrations of Ti and Ni in the floor, platform, and tunnel could indicate the production and disposal of particulate matter from stone tool manufacturing (Table A.4) (Wells 2004: 77). Titanium is found in rocks such as granite and gneiss, which are the parent materials of the soils in this area, suggesting these increases could represent natural variation. However, whetstones and other grinding media made from granite, gneiss, schist, or sandstones could have contained Ti and Ni, which were deposited into dwelling soils as particulate refuse from manufacturing, sharpening, and repairing tools fashioned from these materials. Generally, the primary constituents of slate are muscovite and chlorite, which could contribute K, Al, Ni, Mn, Si, Ti, Mg, and Fe to soil systems associated with tool production areas (Chesterman and Lowe 1979: 530, 531, 535, 732). Considering this, increased concentrations of Ti and Ni could indicate that slate tools were produced and repaired in House 2. Identifying the chemical compositions of lithic tools such as slate blades, soapstone lamps, and grinding media would be useful for identifying traces of their production and use inside dwellings.

House 12 at the Iglosiatik site also has substantial enrichments in several chemical characteristics. The pH and Eh of the soils from this dwelling are respectively more acidic and oxidizing than the control sample, reflecting the deposition of organic refuse from general occupation (Table A.5) (Derry et al. 1998: 204, 208). House 12 has similar elemental increases to those identified in House 2 (Tables A.4 and A.8). However, compared to House 2, the soils from House 12 have higher enrichments in Mg, Ca, P, S, Mn, Ni, and the rare earth elements. In particular, enrichments in the rare earth element

Ce were between 5418% and 8875% higher than the control sample, which are also much higher than the Ce enrichments documented for House 2 (3% - 845%). These enrichments, coupled with the house's bilobate form, suggest that more people occupied House 12, leaving more intense enrichments than those identified in House 2.

The floors of each lobe have increases in similar elements, suggesting the lobes served similar purposes. However, compared to the west lobe, the east lobe has higher enrichments in the elements Cs, Mg, Ca, S, Mn, Fe, and Ni, perhaps indicating a discrepancy in the deposition of both organic and inorganic wastes between these rooms. This suggests that the east lobe could have been abandoned and used as a refuse dump during later reoccupations of the house. Contrary to this, these increases could also indicate a more intense occupation of the east lobe, but this is unlikely because of its small, 8 m^2 interior. Moreover, increases in the rare earth elements are higher in the west lobe's platform, suggesting more intense and/or frequent occupations of this room. However, as mentioned, increases in the rare earth elements could have derived from the decomposition of baleen. House 12 is also the only tested dwelling that has a tunnel alcove. Compared to the control sample, the alcove has increased concentrations of Cs, Mg, Ca, Ba, P, S, Mn, Fe, and Ni, perhaps indicating the deposition of animal remains and charcoal, suggesting it might have been used for storage or temporarily dumping wastes (Parnell et al. 2002: 387). The tunnel also has increases in these elements, perhaps indicating the removal of wastes through the tunnel. Both the alcove and the tunnel have increases in some rare earth elements. The alcove has increases in Sc, Ce, Tm, and Yb and the tunnel has increases in Sc, Y, Ce, Dy, Ho, Er, Tm, and Yb. As mentioned,

enriched rare earths in the tunnel and tunnel alcove could indicate that dogs were kept in these spaces.

The limited testing undertaken within House 4 at Nachvak Village also yielded promising results (Table A.12). The lamp area, which was identified by the presence of a large soapstone lamp and a greasy deposit containing charred materials, has increases in similar elements to the lamp area in House 2 at Iglosiatik. However, the House 4 lamp area has greater chemical enrichments than that of House 2. The lamp area in house 4 has substantial increases in the elements Cs, Ba, P, S, and Pb, indicating the deposition of food wastes (Wilson 2008: 417). The platform area also has increases in these elements, indicating both the proximity of the lamp area to the platform and the conjunctive use of both areas for various activities. In particular, increases in Ba, P, and S in the lamp and platform soils suggest that food was prepared while sitting on the platform's edge, close to the lamp, and consumed either on the interior or edge portions of the platform. Both the lamp and platform areas have substantial increases in most of the rare earth elements, suggesting both areas were intensely occupied.

The soils from House 4 at Nachvak Village have extremely large enrichments in S. The lamp and platform areas have 5200% and 7200% increases over the control value, respectively (Table A.12). As mentioned above, inputs of S could represent the disposal and decomposition of large amounts of organic material such as animal bone and baleen, which likely reflects the use of these areas for preparing and consuming food and making bone tools. As mentioned, cysteine, an amino acid found in baleen, also contains large amounts of S. Accordingly, concentrations of S in the platform could have been a by-product of the decomposition of baleen, which may indicate that a baleen mattress was

used in House 4. This is plausible, given the large amount of baleen recovered from this house. Another potential source for these outlying increases in S is burning seal oil in lamps. Mammals do not produce the amino acid methionine. However, fish do produce methionine. Considering that seals primarily eat fish, they ingest large amounts of methionine, which is incorporated into their fat and oil. Moreover, methionine is an excellent source of S (Figge 2007: 164). During the combustion of seal oil, which is an organic petroleum, S is converted into SO_2 through the catalytic process of hydrodesulphurization, likely concentrating around the lamp area (Sanchez-Delgado 2002: 3). Concentrations of S, then, could be useful for identifying lamp areas that are architecturally ambiguous. However, the deposition of soot on floors, platforms, and roofs, suggest that S should be deposited throughout dwellings. Interestingly, S occurs at elevated levels throughout all of the tested dwellings.

Most of the outlier values are from the Nachvak site (Table B.5). This could indicate that the soils in this area have ideal conditions (i.e. those having poor drainage low mean annual temperatures, high clay contents, and diminished biological and chemical processes) for retaining evidence of anthropogenic eutrophication. However, extreme values in P, S, Cl, Mn, Cu, Zn, Zr, Ce, and Li at Nachvak could also reflect local soil formation conditions, meaning soils in this area have naturally high, and varying, concentrations of these elements. Perhaps the Nachvak values appear as outliers because of a discrepancy in sample extraction methods. The soil samples from Iglosiatik, Komaktorvik, and Big Head were collected by coring dwelling features identifiable on the ground surface. The Nachvak samples, however, were collected during excavations, meaning the samples came directly from occupation layers. Samples extracted using the

corer may have only passed through a small amount of the anthropogenically enriched deposit. This could make elemental concentrations at Nachvak appear higher, strengthening the claim that sampling during excavation produces more accurate and precise results than those obtained through coring.

Soils from Houses 9, 11 and 1 from the Komaktorvik site have similar chemical enrichments. For instance, the soils from each of these houses are more acidic and oxidizing than the control sample (Tables A.13, A.17, and A.21). House 9, similar to the houses discussed above, has increases in the elements K, Rb, Ca, Sr, Ba, P, S, Ti, Cu, Zn, and Pb, suggesting that similar practices, that create similar chemical by-products, were undertaken in houses occupied at approximately the same time in different regions (e.g. House 2 at Iglosiatik and House 9 at Komaktorvik) (Tables A.4 and A.16). Contrasting the houses at Iglosiatik, Houses 9 and 1 at Komaktorvik have enrichments in only two rare earth elements, which are Sc and Ce. Given that rare earth elements are insoluble and generally immobile in soil systems, this discrepancy appears to stem from sampling error (Cook et al. 2005). Sampling issues can be resolved by using a higher resolution sampling program such as a 10 by 10 cm sampling grid over each dwelling.

The elements P, S, Cl, and Sc are enriched in all of the sampled features within House 9 (Table A.16). The floor has the highest concentrations of these elements. In order of decreasing magnitude, the increases in P, S, Cl, and Sc are larger in the tunnel, wall berm, lamp area, and platform. This could indicate that the residues causing these enrichments were initially produced on the floor and platform, perhaps around the lamp, and were later incorporated into the berm and tunnel through refuse disposal practices.

Wastes could have also been accidently dragged around the house during general occupation and while entering and exiting through the tunnel.

House 11 at Komaktorvik has increases in Na, K, Rb, Cs, Sr, Ba, P, S, Pb, Ti, and Cu (Table A.20). Again, enrichments in Na, K, Rb, Cs, Sr, Ba, P, S, and Pb reflect the deposition of organic wastes related to food production and consumption. As mentioned, increased concentrations of Ti could have derived from the deposition of particulate matter generated during lithic tool production. Inuit people also made tools and items of personal adornment from Cu such as brow bands, which could contribute to the increased Cu concentrations within the floor and platform soils of House 11. The south platform, as mentioned above, has a higher elevation than the others, has thicker, greener vegetation, and has a darker soil with visible charcoal inclusions. Of the three, the south platform also has the largest enrichments in Na, Sr, P, S, Cl, and Pb, reflecting the deposition of relatively larger amounts of organic and charred wastes, which could indicate its use as, or proximity to, a lamp/cooking area. The rare earth elements Sc, Y, La, Ce, Pr, Nd, Tb, Dy, Ho, Er, Tm, Yb, and Lu are also increased in House 11 (Table A.20). These increases indicate that evidence of their enrichment can be preserved in Komaktorvik soils, strengthening the claim that sampling error caused their absence in Houses 9 and 1. This also suggests that too few samples were collected from each context.

House 1, as with the other houses at Komaktorvik, has substantial increases in the elements K, Rb, Cs, Sr, Ba, P, S, Cl, Ti, Cu, Pb, Sc, La, Ce, and Ta (Table A.24). However, compared to the other two houses, the increases in the House 1 soils are much more intense. This could indicate that House 1 was reoccupied more often, or by more people, producing large quantities of organic and inorganic wastes. In particular, P

concentrations in the floors of Houses 9, 11, and 1 could indicate the intensity or length of occupation within each house. House 1 has the highest P concentration followed by House 9 and lastly House 11. This suggests that House 1 was the most intensely occupied. This is interesting, given that Kaplan (1983: 710) identified at least three separate occupations in House 1. Moreover, house forms similar to that of Houses 9 and 1 were common for longer periods. The communal house style was commonly used during the 18th and early19th centuries in northern Labrador, meaning House 11 could have been used for much less time than Houses 9 and 1. However, House 1 was also occupied during the 19th century, which is likely much later than most of the other houses at Komaktorvik. This late occupation suggests that the residues causing the enrichments in House 1 were also deposited later, meaning the enrichments in the other houses have had more time to deteriorate within the soil system. Enrichments of K, Rb, Cs, Sr, Ba, P, S, Ti, Sc, and Pb in the berm also suggests that wastes from the interior of the house were often incorporated into the berm, which explains the lush growth of grass over the berm of House 9.

The two samples collected from the Big Head site, which were from a house floor and a midden, have enrichments similar to those discussed above (Table A.28). The floor of House 3 has the greatest increases of K, Rb, Cs, Sr, Ba, Zn, Pb, La, Pr, and Nd encountered in all of the tested floor contexts. These anthropogenic enrichments contributed to the luxuriant grass growing over the house mound at Big Head, and could indicate a more intense occupation or the soil's ability to retain evidence of anthropogenic eutrophication. These intense increases also indicate that the Big Head site could be an excellent candidate for future geochemical testing.

Regarding the middens tested at Nachvak, Komaktorvik, and Big Head, I expected to see increases in the same elements as the houses. I also expected to see the largest enrichments in the middens, given they were used for the disposal of wastes produced mainly within dwellings. The middens have increases in many of the same elements that are increased in the houses, which are K, P, S, Cl, Rb, Cs, Sr, Ba, S, Cl, Ti, Ni, Cu, Zn, Pb, Sc, Ce, Pr, Eu, Gd, Tb, Dy, Ho, Er, Tm, Tb, Lu, and Ta (Tables A.12, A.24, and A.28). All of the tested middens have rather large increases in Ba, P, S, Cl, and Pb. Three of four middens have increases in Cs, Sr, and Ce. Beck (2007: 468) argues that elements, particularly those contained in organic wastes, typically have higher concentrations in middens than in dwellings, reflecting the disposal of wastes produced within the dwelling. Compared to the dwellings, the middens generally did have larger concentrations of most elements. All of the midden soils are also more acidic and oxidizing than those from houses, indicating relatively large accumulations of organic wastes. Based on P concentrations, the middens at Nachvak appear to be the most intensely used. In particular, the midden associated with House 2 (IgCx-3) has the highest P enrichment. House 2 (IgCx-3) has a bilobate form, meaning it housed more people that generated more wastes, which explains the large enrichment in P. However, it is strange that the middens have no increases in Na, Ca, and Mg, which are commonly associated with decomposing animal remains and charred materials. Actually, most of the tested contexts had either no increases or very modest increases in Na, Ca, and Mg, which could indicate that these elements are unstable in northern Labrador soils and share similar degradation pathways.

Elements were grouped according to the number of sites on which they were enriched to identify their importance for distinguishing Labrador Inuit archaeological sites from adjacent non-habitation areas. The elements increased in soils at all four sites are P, S, and Cl. Independent samples t-tests demonstrate that on-site increases in the means of these elements are statistically significant, meaning they are important for geochemically distinguishing Inuit sites in northern Labrador from adjacent control areas. Elements with statistically significant increases on three of the four study sites are Cs, Ba, Ti, and Pb, suggesting they are also important for geochemically distinguishing Inuit occupations in northern Labrador. Increases in pH, Eh, P, S, Cl, Ca, Ba, and Ti in most of the tested contexts suggest they are useful for identifying general habitation, which could be useful for identifying ephemeral occupations having sparse artefactual and architectural evidence, such as summer tents.

The elements with comparable mean concentrations on all of the sites are V, Mn, Fe, Ga, Sr, Y, Cs, Sm, Eu, Ta, Dy, Ho, Yb, Tb, Lu, and Tm, suggesting the sites have similar soil chemistries. The results of the independent-samples t-tests, however, suggest that the sites are geochemically distinct, possibly owing to localized environmental conditions (e.g. parent material, weathering, and topography) (Tables B.10 to B.17). The Iglosiatik site has significant increases in 32 elements, which is far more than the other three sites. The Iglosiatik soils have higher clay and organic contents, meaning they are better at retaining water, which should help anthropogenic elemental enrichments withstand eluviation. Differences in average P concentrations between the sites could indicate the intensity or duration of human habitation at each site (Linderholm 2007: 419; Beck 2007: 469). The mean P concentrations for Iglosiatik, Nachvak, Komaktorvik, and

Big Head are 0.20%, 1.40%, 0.44%, and 1.15% respectively (Tables B.10, B.12, B.14, and B.16). These increases could indicate that the Nachvak and Big Head sites were the most intensely occupied. The relatively low mean concentration of P at Iglosiatik could indicate that it was a gateway community, or a staging ground for identifying regions that would provide adequate resources for the group. Perhaps the most interesting difference between the sites is that Mg, Ca, and Mn are enhanced exclusively at the Iglosiatik site (Tables B.10, B.12, B14, and B.16). The tree line in northern Labrador is located near Okak, meaning Iglosiatik is in an area where trees are abundant and Nachvak, Komaktorvik, and Big Head are not (Kaplan 1983: 66). This could reflect greater access to wood for use as fuel at Iglosiatik. Wood is scarce in the Torngats, meaning it may have been more valuable and was burned less frequently. Most sampling contexts have increases in the elements Li, Cl, V, Zr, Nb, Mo, Ga, Hf, Ta, and Th. The increases in these elements could derive from natural variability. Increases in Cl, for example, could derive from an unequal deposition of seawater. More experimental and ethnoarchaeological research is necessary to discern the relationship between these elements and cultural practice.

The Geochemical Attributes of Labrador Inuit Taskscapes

The series of PCA suggests that lamp areas, sleeping platforms, the tunnel alcove, tunnels, and middens have geochemically distinct soils. Soapstone lamps, fuelled with either whale or seal fat, were probably the focal points of Inuit winter dwellings. People likely gathered around lamps, telling stories, teaching children, preparing and consuming food, and making tools. Archaeologically, their locations within winter dwellings are denoted by grease and oil deposits both on and below floors (Farid 2001: 30). Whitridge

(2002: 166; 2004a: 45-47) notes that lamp areas are typically dominated by refuse indicative of female activities, suggesting lamp areas represent female space and labour. Grinding, mixing, cooking, and distributing food, which likely took place around the lamp area, were primarily the responsibilities of women (Giffen 1930: 15). As such, any geochemical signature associated with lamp areas soils is likely produced by activities commonly performed by Inuit women.

Atalay and Hastorf (2006: 284, 314) argue that the spatial distribution of food refuse reflects the organization of daily life. Accordingly, the spatial distributions of chemical residues from food-related activities are equally useful. In Inuit society, lamps were sometimes used for cooking meat, which was held on either skewers or hooks, or placed in pots (Maxwell 1985: 264). Cooking areas are evident through large concentrations of bone refuse, bone and grease stains, and organic-rich soils (Farid 2001: 30). Logged means show that Ba and S have large concentrations in lamp areas, perhaps indicating large accumulations of food refuse and soot produced by cooking (Figures B.27 and B.28) (Wilson 2008: 417). Principal components analysis also indicates that soil associated with lamp areas have characteristically high concentrations of the rare earth elements Ce, La, Pr, and Nd, perhaps deriving from general human detritus such as shed hair, skin, and fingernails (Figure B.31). Spending more time in a given area provides more opportunity for general human detritus to accumulate. This could indicate that lamp areas were some of the most frequently occupied dwelling spaces.

Additionally, bone tools such as harpoon heads, sled runners, snow knives, mattocks, combs, needle cases, knife handles, and bow drill handles were manufactured in winter dwellings (McCartney 1979a: 306). Consequently, particulate material from the

production of these tools can accumulate in the soils of house floors and platforms. Following Dawson et al. (2007: 19), perhaps carving, grinding, and polishing bone into various objects required the light of the lamp. Interestingly, the logged means of P and K, which could indicate the deposition of particulate matter from bone tool production, are high in lamp areas and floors (Figures B.26 and B.28). However, increased concentrations of P and K could also reflect the deposition of charred materials or organic refuse (Middleton and Price 1996: 679, 680). Elevated mean concentrations of Rb in floors and platforms could also reflect the presence of charred materials (Entwistle et al. 2000: 296, 297). The mean concentrations of P, K, and Rb in platform contexts indicate their proximity to lamps (i.e. the sources of charred materials) (Figures B.26 and B.28).

Mathiassen (1927, 1930) observed that lamp areas were typically located adjacent to sleeping platforms, because many tasks requiring the use of the lamp could be done comfortably while sitting on the platform's edge, such as tending the lamp, cooking, or using its light to carve a tool. Sleeping platforms are also associated with the refuse of male activities, and can thus be considered primarily a male activity area (Whitridge 2002: 166, 2004a: 45-47). Mathiassen (1927) also observed that tool manufacturing was confined to sleeping platforms. Manufacturing stone tools such as slate endblades and knives and soapstone vessels involves grinding, drilling, and polishing, producing particulate by-products that become incorporated into the soil beneath the floor or platform. The logged means of K and Ti are slightly higher in floor and platform contexts, which could indicate that stone tools were manufactured and repaired in these spaces (Figures B.26 and B.29) (Wells 2004: 77, 80). This could also reflect that male oriented activates, including tool manufacturing, produced a unique geochemical

signature in platform areas, though more research is required to adequately assess this hypothesis.

Principal components analysis identified that Labrador Inuit sleeping platforms have characteristically large increases in Gd, Tb, Ho, Er, and Sm (Figure B.32). As mentioned, these rare earth elements could be enhanced because of inputs of hair, skin, and baleen (Cook et al. 2005: 630, 638). High concentrations in these elements could indicate that most general human detritus accumulated in platform areas, strengthening the interpretation that they were among the most frequently occupied places inside Inuit winter dwellings. However, Inuit sleeping platforms were often covered with baleen mattresses and caribou hides. Baleen, as mentioned, is composed of keratin, which could have contributed rare earth elements and S to platform soils. Interestingly, mean S concentrations have substantial increases in all of the tested platforms, perhaps indicating the use of baleen mattresses in all of the tested houses (Figure B.28). Moreover, hair from the hides used on the platforms could have also enriched the rare earth elements in platform soils.

Inuit people stored meat in stone lockers within their houses, in storage alcoves off entrance tunnels, or in nearby boulder caches (Maxwell 1985: 281; Dawson and Levy 2005: 445). Principal components analysis determined that the tunnel alcove is associated with characteristically high concentrations of K, Rb, Cs, Na, Sr, Ba, Nb, Zr, Ga, Mo, Pb, and Hf (Figures B.26, B.27, and B.30). Increased concentrations of K, Rb, Ba, Na, and Sr could indicate that the alcove was used for storing whale, fish, seal, or caribou (Entwistle et al. 2000: 296-300; Knudson et al. 2003: 451). However, enrichments in K, Rb, Cs, Na, Sr, Ba, and Pb could also indicate the deposition of organic refuse from the interior of the

house (Wilson et al. 2008: 461, 417). Ethnographic evidence suggests that tunnel alcoves were used for storing food or other items used in the dwelling (Farid 2001: 30). Principal components also determined that the rare earth elements Eu and Sm are associated with the tunnel context and Sc with the tunnel alcove. As mentioned, dogs were often kept in entrance tunnels. Following Cook et al. (2005: 630, 638), increases in these rare earth elements could signify the deposition of dog hair.

Housekeeping practices such as cleaning equipment and disposing of refuse were woman's responsibilities (Giffen 1930: 31, 32). Following McCartney's (1979a: 307) consideration of the life histories of Thule Inuit houses, chemical eutrophication on the test sites could reflect the seasonal dismantling and cleaning of winter dwellings. During spring, the wastes that accumulated on floors and in tunnels throughout the winter were gathered and discarded next to tunnel mouths (Farid 2001: 30). Habu and Savelle (1994: 12) also assert that Inuit winter houses were seasonally cleaned and reused. Refuse was either swept to the outside midden via the tunnel or incorporated into wall berms.

Comparisons of logged means indicate that the most acidic sampling context is the lamp area, followed by the berm, alcove, floor, midden, tunnel, and platform contexts (Figure B.25). Means for P, S, Ca, and K are higher in walls, tunnels, and middens than floors (Figures B.26 to B.28). Floors, however, do have increased concentrations of P, S, K, Pb, Ba, Ho, Eu, Sc, and Ti, which could reflect accumulations of organic and inorganic refuse initially produced around lamps and platform edges (Figures B.27 to B.32). Principal components analysis also indicated that soils from entrances have high concentrations of Mn, Ba, and Sr, and soils from middens have increases in P, S, Sc, Cu, Fe, Pb, Mn, Zn, Ba, and Sr (Figures B.27 to B.30). Increases in the elements P, S, Ca,

Mn, Ba, Sr, and Pb could represent an accumulation of by-products from the deposition and subsequent decomposition of animal remains (Sampietro and Vattuone 2005: 348; Wilson et al. 2008: 417). However, increases in P, K, and Ca could also represent the deposition of charred materials (Moore and Denton 1988). Enrichments in Cu and Fe could indicate the deposition of micro-debitage from tool (metal or stone) manufacturing (Wells 2004). Following McCartney (1979a: 307) and Habu and Savelle (1994: 12), these results reflect patterned behaviours related to refuse disposal. Perhaps these geochemical signatures also reflect patterned gendered tasks.

Summary

Combining the concepts of practice, dwelling taskscapes, and soilscapes with data obtained from high resolution geoanalytical techniques provides unique insight into the organization of Inuit household practices. Inuit people practiced similar dwelling oriented activities over time and in different regions because of enduring social expectations for such behaviours. Comparisons of raw data and means between control and habitation samples, as well as a series PCA, identified spatial variability in several soil chemical characteristics. This variability likely represents that different cultural practices were enacted in the tested spaces. The analyses, coupled with comparative research, identified enrichments potentially produced by food production and consumption, trash disposal practices, tool manufacturing, keeping dogs, tending lamps, and even the use of baleen in platform areas. Eutrophication in Inuit dwelling soilscapes appears to reflect patterned behaviour, or the formation of taskscapes, which is useful for identifying the spatially oriented activities that occurred inside these dwellings. However, Moore and Denton (1988: 27) warn that soil chemistry notoriously variable naturally, meaning caution must

be exercised when interpreting how eutrophication relates to human behaviour. Considering the parent geology of the soils in the research locations, the elements Ca, Na, Mg, Fe, Al, and K are naturally abundant, and their increases could simply be because of natural variation. Moreover, many of the observed increases could have arisen from the deposition of seawater, as all of the sites are close to the ocean. More research is necessary to confidently rule out any natural sources of enrichment.

CHAPTER SEVEN

CONCLUSION

Inuit activities such as manufacturing tools, preparing and storing food, and disposing of organic refuse produce chemical residues that accumulate in dwelling soils, forming soilscapes, or soils containing a chemical record of the cultural practices that contributed to their formation. Subsequently, spatially patterned chemical concentrations in these soils reflect spatially oriented taskscapes. Simply put, dwelling soilscapes are chemical records of Labrador Inuit practices, and are another source of archaeological evidence useful for understanding concepts of Inuit spatial organization. However, additional, higher resolution data are necessary to fully realize the potential of archaeopedology on Inuit sites.

Inuit archaeological sites in northern Labrador have cold soils with diminished chemical and biological activity and are uninfluenced by modern land use, which appears to benefit the preservation of anthropogenically enriched soil characteristics. Soil samples were collected from two winter dwellings at Iglosiatik 1, one at Nachvak Village, three at Komaktorvik 1, and one at Big Head 1 in northern Labrador. Specifically, soils from seven floors, nine platforms, four lamp areas, six tunnels, one tunnel alcove, three berms, four middens, and four control areas were collected for geochemical analyses (n=38). Control samples were taken approximately 40 to 100 m away from the nearest dwelling or feature on each site, from areas with similar elevations, geology, pedology, and vegetation. These samples were used as a comparative baseline for the archaeological samples, which proved useful for identifying anthropogenically eutrophied

characteristics. The chemical reactivity (i.e. pH, Eh, and TDS) of each sample was measured in a 1:2 solution of soil to distilled water using electronic, chemically calibrated meters. Element concentrations were quantified using XRF and ICP-MS. Forty-five elements underwent measurement. As mentioned, I focused on the inorganic chemistry of the sampled soils because of time and resource restraints. The only error encountered in the geochemical analyses was poor Zr dissolution.

Kolmogorov-Smirnov, skewness, and kurtosis statistics identified that the geochemical dataset is not normally distributed. The data were subsequently normalized using a base 10 logarithm plus 1. Outliers were identified using box and whisker plots and subsequently recoded. Independent-samples t-tests were used to identify statistically significant differences between the control and on-site soils samples. These tests identified that 34 elements have statistically significant increases in at least one sampling context, indicating that Inuit archaeological sites in northern Labrador are distinguishable from adjacent non-habitation areas based on their soil chemistry.

Principal components analysis identified latent variables providing the data with structure. Given the large number of variables and relatively small number of cases considered, seven sets of elements were analyzed separately based on their periodic group. I also maintained a low variable to case sampling ratio to avoid the generation of spurious components. The analyses passed the requisite statistical assumptions. The determinant values indicated that multicollinearity is not a problem, and the Kaiser-Meyer-Olkin values indicated an adequate amount of samples. Bartlett's test of sphericity also demonstrated that the correlation matrices are not identity matrices, so the extracted components are statistically reliable. In each analysis, components with eigenvalues over

one were extracted, rotated, and interpreted because they account for most of the variation in the data. The series of analyses identified five different principal components. The latent variables represented by these components were defined by identifying similarities in the logged mean of each element across the sampling contexts. This revealed that sleeping platforms, lamp areas, the tunnel alcove, entrances, and middens have characteristically large enrichments in distinct suites of elements.

Considering the PCA results, the internal features of Labrador Inuit winter dwellings are both architecturally and geochemically distinct. Platform and lamp areas are associated with the highest concentrations of Gd, Tb, Ho, Er, and Sm and Ce, La, Pr, and Nd respectively, suggesting large inputs of general human detritus such as shed hair, skin, fingernails, and perhaps the presence of baleen. This could indicate that these areas were the most frequently occupied within Inuit winter dwellings. The tunnel alcove might have been used for storing whale, caribou, seal, or fish, which is suggested by elevated concentrations of K, Rb, Cs, and Na. Tunnel contexts are associated with high concentrations of Mn, Ba, and Sr, suggesting the disposal of organic wastes. Midden soils were also associated with high increases in P, S, Mn, Ba, and Sr, also owing to practices related to the disposal of organic food wastes.

Patterns in pH, P, S, and K also suggest that refuse was originally discarded on floors, mostly near lamp areas. Eventually, wastes that accumulated on the floors were pushed to the sides of the interiors and incorporated into wall berms during seasonal rebuilding, explaining the overgrowth of vegetation associated with the walls of Inuit houses. Refuse was also tossed into the tunnel and later moved to middens next to tunnel mouths.

Social structures are reproduced over time and space by people's informed, reflexive actions, or the construction and perpetuation of symbolic perceptions, shared memories, community identities, and tacit knowledge. Archaeological considerations of practice typically focus on how social reproduction is reflected through materiality. This thesis considered the chemical by-products of household practices as material evidence for the reproduction of Inuit ideas concerning the use of dwelling space, which involved integrating the concepts of practice, *habitus*, social memory, social expectations, structuration, and social monitoring, dwelling taskscapes/activity areas, and soilscapes with geochemical data.

Winter dwellings were places of social and cultural reproduction in past Inuit societies. These houses were arenas for social interaction, and the interaction that occurred inside them generated expectations for behaviours and activities acceptable in that field, which over time formed a set of specific dispositions that influenced decisions of how space inside winter houses should be used. Moreover, winter houses both enabled and constrained activities. They provided a place where various tasks could be performed. The unique geochemical signatures identified in soils associated with Inuit dwelling spaces suggest that social expectations encouraged spatially organized, routine behaviours, including tool manufacturing, tending lamps, and refuse disposal. Chemically distinguishable soils associated with spaces inside Labrador Inuit winter dwellings represent taskscapes, or places where particular practices were socially accepted. Considering this, similar household tasks were performed in the same places over time, causing spatially discrete accumulations of chemical residues. The dwellings included in this exploration represent different regional and temporal contexts, and the analytical

results suggest some degree of symmetry in the spatially oriented activities preformed in these houses, suggesting the reproduction of social expectations for the use of dwelling taskscapes over time and space. This also suggests that the practices performed inside Inuit winter dwellings were the product of mutual social histories.

Though the results of this project are promising, some minor problems were encountered, which is beneficial because these problems can now be anticipated and avoided when developing and conducting similar projects. A larger budget for geochemical analyses would have enabled the collection of more samples, perhaps using a high resolution grid system over each dwelling. With a larger budget, I could have also collected more control samples to establish a higher resolution natural baseline for comparison with the archaeological samples. Undertaking a single PCA on a dataset with 45 variables (i.e. elements) necessitates over 300 soil samples, which would require a rather large analysis budget. With a larger analysis budget, I could also consider the organic chemistry of Inuit soilscapes using Fourier transform infrared spectroscopy.

Additionally, the sites investigated have multiple Palaeoeskimo and Inuit occupations, which complicates identifying the sources of any observed eutrophication. Many Labrador Inuit sites were initially occupied by Predorset and Dorset people. The effects they had on the soil system could obscure those caused by Inuit people and vice versa. Essentially, the archaeological record is a palimpsest, meaning older evidence of human activity can be obscured by newer evidence. Considering this, properly indentifying sampling contexts is very important when conducting archaeopedological research. Equifinality might also be an issue, meaning that similar behavioural, or even natural, processes can produce similar geochemical signatures. For example, debitage

from bone tool manufacturing could produce a geochemical signature similar to those of cooking or disposing of food remains and charred materials. Properly identifying sampling contexts should help avoid this problem. Combining the spatial distribution of material culture with patterns of chemical enrichments can also help avoid this issue. The decomposition of building materials (e.g. baleen, bone, and wood) can also leave chemical signatures in Inuit soilscapes. As such, these signatures can become confused with actual activity areas. More research is necessary to determine how the impacts of building materials and activity areas can be distinguished.

Using a 1 by 1 m sampling grid over an entire site and a 10 by 10 cm grid over each dwelling could be used to produce high resolution isopleth maps of element concentrations, which when combined with architectural features and the spatial distribution of material culture, would aid the identification and interpretation of activity areas. Sampling occupation layers within dwellings during excavation rather than coring could also provide more accurate and precise results. Research clarifying relationships between soil properties such as pH, Eh, and hydrology with eutrophication survivorship on archaeological sites would be beneficial. Additional experimental and ethnoarchaeological research is also required to better define the geochemical fingerprints of particular Inuit practices. In particular, more research is necessary to define the anthropogenic sources of Li, Cl, V, Zr, Nb, Mo, Ga, Hf, and the rare earth elements. Additional research is also required to understand how the geochemical signatures in Inuit dwelling taskscapes relate to gendered spaces and activities. Isopleth maps coupled with spatial analysis (e.g. k-means analysis) of material culture distributions will help assess this relationship.

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APPENDIX A:

SOIL CHEMICAL DATA FROM FOUR INUIT ARCHAEOLGICAL SITES IN NORTHERN LABRADOR

Table A.1: Chemical Reactivity Data for House 2, Iglosiatik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm
pH	5.47	5.30	5.60	4.66	4.29	4.22
Eh[a]	181.7	240.3	182.8	273.8	280.1	288.4
TDS[b]	100	880	20	820	320	650

a=mV; b–ppm

Table A.2: XRF Data for House 2, Iglosiatik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm
Na[a]	3.20%	3.13%	2.96%	2.88%	2.45%	2.68%
Mg[a]	0.79%	0.74%	0.82%	0.75%	0.84%	0.61%
Al[a]	14.31%	15.02%	14.55%	13.93%	13.23%	13.42%
P[a]	0.13%	0.19%	0.16%	0.18%	0.21%	0.26%
K[a]	3.31%	3.41%	3.17%	3.14%	2.98%	2.98%
Ca[a]	2.60%	2.55%	2.66%	2.54%	2.69%	2.44%
Mn[a]	0.03%	0.03%	0.04%	0.03%	0.04%	0.03%
Fe[a]	2.35%	2.12%	2.53%	2.39%	2.87%	2.46%
S	262	319	595	455	1071	1401
Cl	224	237	291	295	381	349
Sc	LD	LD	LD	LD	LD	LD
V	29	24	23	22	35	22
Cr	32	6	29	24	27	11
Ni	LD	LD	6.41	4.53	8.40	LD
Cu	LD	LD	LD	LD	16.56	LD
Zn	LD	LD	LD	LD	LD	LD
Ga	16.02	18.22	19.27	17.39	17.97	16.73
Rb	74.62	79.00	72.75	74.76	71.95	66.32
Sr	304.11	309.94	303.19	297.58	289.77	267.76
Y	9.20	7.94	9.56	9.23	11.15	8.00
Zr	100.58	70.18	127.85	100.31	123.62	107.90
Nb	5.38	5.33	7.13	6.29	6.64	6.35
Ba	1301.28	1330.98	1309.18	1331.47	1382.43	1326.37
Ce	LD	75.67	81.03	85.91	133.64	85.43

a reported in % weight of their oxide; remaining elements reported in ppm

Table A.3: ICP-MS Data for House 2, Iglosiatik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm
Li	10.509	10.632	10.200	11.249	9.988	7.333
Rb	74.962	75.684	71.817	72.640	70.641	66.239
Sr	304.36	299.42	297.93	291.30	298.19	269.11
Y	9.780	9.260	11.478	11.312	12.512	10.242
Nb	7.757	5.058	8.827	8.123	9.628	7.268
Mo	LD	1.500	2.475	1.825	1.687	1.701
Cs	0.353	0.478	0.434	0.437	0.444	0.411
Ba	1553.92	1585.05	1512.27	1547.22	1452.39	1325.01
La	19.895	21.629	22.672	21.890	31.771	18.543
Ce	37.391	38.433	43.090	41.132	57.934	35.812
Pr	4.285	4.439	4.971	4.740	6.680	4.017
Nd	15.571	15.762	18.312	17.420	23.796	14.702
Sm	2.565	2.701	3.220	2.970	3.954	2.601
Eu	1.423	1.550	1.578	1.524	1.566	1.357
Gd	1.953	2.043	2.469	2.310	2.778	1.898
Tb	0.283	0.300	0.358	0.353	0.404	0.312
Dy	1.911	1.913	2.409	2.340	2.673	1.977
Ho	0.354	0.370	0.457	0.443	0.486	0.382
Er	0.990	1.077	1.307	1.302	1.357	1.089
Tm	0.152	0.170	0.181	0.179	0.213	0.176
Yb	0.812	0.966	1.206	1.205	1.160	1.015
Lu	0.101	0.138	0.169	0.171	0.155	0.140
Hf	0.842	1.267	1.562	1.996	1.359	2.174
Ta	1.192	1.107	1.266	1.102	0.965	1.605
Ti	0.337	0.406	0.353	0.356	0.355	0.370
Pb	18.144	17.806	16.870	16.461	15.895	15.758
Th	2.309	3.024	2.983	2.609	2.692	1.699

All elements reported in ppm

Table A.4: Increased Elements for House 2, Iglosiatik 1

	Floor	Platform	Lamp Area	Tunnel	Berm
Li	1%	---	7%	---	---
Na	---	---	---	---	---
K	3%	---	---	---	---
Rb	1%	---	---	---	---
Cs	35%	23%	24%	26%	16%
Mg	---	4%	---	6%	---
Ca	---	2%	---	---	---
Sr	2%	---	---	---	---
Ba	2%	1%	2%	6%	2%
P	46%	23%	38%	62%	100%
S	19%	127%	74%	309%	435%
Cl	6%	30%	32%	70%	56%
Al	---	---	---	---	---
Ti	20%	5%	6%	---	10%
V	---	---	---	21%	---
Cr	---	---	---	---	---
Mn	---	33%	---	33%	---
Fe	---	---	---	---	---
Ni	---	641%	453%	840%	---
Cu	---	---	---	1656%	---
Zn	---	---	---	---	---
Zr	---	27%	---	23%	7%
Nb	---	14%	5%	24%	18%
Mo	150%	250%	180%	168%	170%
Pb	---	---	---	---	---
Ga	14%	20%	9%	12%	4%
Hf	50%	86%	137%	61%	158%
Sc	---	---	---	3%	5%
Y	---	17%	16%	28%	---
La	---	---	---	---	---
Ce	3%	15%	10%	55%	854%
Pr	4%	16%	11%	56%	---
Nd	1%	18%	12%	53%	---
Sm	5%	26%	16%	54%	2%
Eu	9%	11%	7%	10%	---
Gd	5%	26%	18%	42%	---
Tb	6%	27%	25%	43%	10%
Dy	---	26%	22%	40%	3%
Ho	5%	29%	25%	37%	8%
Er	9%	32%	32%	37%	10%
Tm	12%	19%	15%	40%	16%
Yb	19%	49%	48%	43%	25%
Lu	37%	67%	69%	53%	39%
Ta	---	6%	---	---	35%
Th	31%	29%	13%	17%	---

Table A.5: Chemical Reactivity Data for House 12, Iglosiatik 1

	Control	West Floor	West Platform	East Floor	East Platform	Tunnel Alcove	Tunnel
pH	5.47	4.65	4.76	4.24	5.20	4.62	4.15
Eh[a]	181.7	237.0	281.0	260.6	206.4	256.4	291.1
TDS[b]	100	90	230	720	30	530	510

a=mV; b=ppm

Table A.6: XRF Data for House 12, Iglosiatik

	Control	West Floor	West Platform	East Floor	East Platform	Tunnel Alcove	Tunnel
Na[a]	3.20%	2.92%	3.33%	3.15%	3.04%	3.18%	2.90%
Mg[a]	0.79%	0.82%	1.06%	1.08%	0.92%	0.80%	0.86%
Al[a]	14.31%	13.56%	14.44%	14.17%	14.23%	14.18%	13.29%
P[a]	0.13%	0.24%	0.15%	0.23%	0.23%	0.20%	0.21%
K[a]	3.31%	3.10%	3.15%	3.11%	3.15%	3.24%	3.06%
Ca[a]	2.60%	2.64%	2.85%	2.75%	2.76%	2.63%	2.64%
Mn[a]	0.03%	0.04%	0.04%	0.05%	0.04%	0.08%	0.04%
Fe[a]	2.35%	2.70%	3.04%	3.10%	2.80%	2.51%	2.76%
S	262	559	407	622	451	550	710
Cl	224	278	259	262	269	266	288
Sc	LD	9	LD	LD	20	17	9
V	29	25	33	30	27	28	32
Cr	32	15	29	30	39	24	19
Ni	LD	LD	4.69	6.42	LD	4.34	LD
Cu	LD	LD	LD	LD	LD	LD	LD
Zn	LD	LD	LD	LD	LD	LD	LD
Ga	16.02	17.41	17.02	17.43	17.80	18.84	19.44
Rb	74.62	72.02	72.68	71.97	74.46	74.38	75.24
Sr	304.11	300.25	298.60	294.00	304.93	297.01	303.56
Y	9.20	8.31	10.71	10.15	9.49	7.75	8.60
Zr	100.58	113.54	179.91	116.64	134.69	134.22	147.66
Nb	5.38	6.81	8.03	8.31	6.35	5.89	7.26
Ba	1301.28	1315.68	1221.88	1213.09	1263.03	1317.94	1325.52
Ce	LD	88.75	LD	57.08	54.18	58.98	74.20

a= reported in % weight of their oxide; remaining elements reported in ppm

Table A.7: ICP-MS Data for House 12, Iglosiatik 1

	Control	West Floor	West Platform	East Floor	East Platform	Tunnel Alcove	Tunnel
Li	10.509	9.468	9.502	9.253	10.093	8.352	9.218
Rb	74.962	67.228	72.684	69.213	74.959	72.081	73.444
Sr	304.36	291.17	308.81	288.34	314.60	303.27	304.21
Y	9.780	10.007	12.043	11.982	10.294	9.553	9.976
Nb	7.757	8.705	10.927	9.857	6.087	7.422	11.625
Mo	LD	2.039	1.555	1.498	1.648	1.937	1.581
Cs	0.353	0.428	0.418	0.408	0.449	0.420	0.448
Ba	1553.92	1483.78	1490.00	1417.67	1592.17	1472.63	1491.64
La	19.895	18.001	19.665	18.675	19.668	18.464	19.544
Ce	37.391	34.560	37.347	36.354	36.727	34.799	35.491
Pr	4.285	4.078	4.486	4.403	4.239	4.057	4.145
Nd	15.571	15.260	16.657	16.008	15.317	14.825	14.865
Sm	2.565	2.691	3.005	2.891	2.494	2.444	2.488
Eu	1.423	1.425	1.457	1.363	1.504	1.350	1.367
Gd	1.953	2.014	2.349	2.270	1.921	1.917	1.881
Tb	0.283	0.309	0.373	0.345	0.296	0.277	0.268
Dy	1.911	2.017	2.487	2.450	2.051	1.827	1.977
Ho	0.354	0.398	0.499	0.468	0.397	0.351	0.379
Er	0.990	1.137	1.401	1.300	1.110	0.943	1.049
Tm	0.152	0.187	0.191	0.208	0.183	0.169	0.192
Yb	0.812	1.002	1.277	1.211	1.035	0.905	0.962
Lu	0.101	0.143	0.188	0.178	0.137	0.115	0.129
Hf	0.842	1.247	2.161	1.526	1.201	1.504	1.302
Ta	1.192	1.197	1.782	1.500	0.886	1.163	1.205
Ti	0.337	0.346	0.316	0.346	0.375	0.359	0.376
Pb	18.144	16.359	17.538	16.588	17.245	19.111	18.675
Th	2.309	1.904	2.601	2.431	2.024	2.447	2.096

All elements reported in ppm

Table A.8: Increased Elements for House 12, Iglosiatik 1

	West Floor	West Platform	East Floor	East Platform	Alcove	Tunnel
Li	---	---	---	---	---	---
Na	---	4%	---	---	---	---
K	---	---	---	---	---	0%
Rb	---	---	---	---	---	1%
Cs	21%	18%	16%	27%	19%	27%
Mg	4%	34%	37%	16%	1%	9%
Ca	2%	10%	6%	6%	1%	2%
Sr	---	2%	---	3%	---	---
Ba	1%	---	---	2%	1%	2%
P	84%	15%	77%	77%	54%	62%
S	113%	55%	137%	72%	110%	171%
Cl	24%	15%	17%	20%	19%	29%
Al	---	---	---	---	---	---
Ti	---	---	---	---	---	---
V	---	14%	---	---	---	10%
Cr	---	---	---	22%	---	---
Mn	33%	33%	67%	33%	166%	33%
Fe	15%	29%	32%	19%	7%	17%
Ni	---	469%	642%	---	434%	---
Cu	---	---	---	---	---	---
Zn	---	---	---	---	---	---
Zr	13%	79%	16%	34%	34%	47%
Nb	12%	41%	27%	18%	9%	50%
Mo	200%	155%	150%	164%	193%	158%
Pb	---	---	---	---	5%	---
Ga	9%	6%	9%	11%	18%	21%
Hf	48%	156%	81%	43%	79%	55%
Sc	90%	---	---	200%	170%	90%
Y	2%	23%	23%	5%	---	2%
La	---	---	---	---	---	---
Ce	8875%	---	5708%	5418%	5898%	7420%
Pr	---	5%	3%	---	---	---
Nd	---	7%	3%	---	---	---
Sm	5%	17%	---	---	---	---
Eu	---	---	---	6%	---	---
Gd	3%	20%	16%	---	---	---
Tb	9%	32%	22%	5%	---	---
Dy	5%	31%	---	7%	---	3%
Ho	12%	41%	---	12%	---	7%
Er	15%	41%	---	12%	---	6%
Tm	23%	26%	---	20%	11%	3%
Yb	23%	51%	49%	27%	11%	18%
Lu	42%	86%	76%	36%	14%	28%
Ta	---	---	---	---	---	---
Th	---	13%	5%	---	6%	---

Table A.9: Chemical Reactivity Data for Nachvak Village

	Control	H4 Platform	H4 Lamp Area	H4 Tunnel	H2 Midden	H10 Midden
pH	5.72	4.53	4.58	5.05	4.69	4.98
Eh[a]	209.2	241.9	202.2	228.9	221.1	229.5
TDS[b]	120	150	90	90	120	90

a=mV; b=ppm

Table A.10: XRF Data for Nachvak Village

	Control	H4 Lamp Area	H4 Sleeping Platform	H4 Tunnel	H2 Midden	H10 Midden
Na[a]	2.56	0.47	0.65	1.22	1.40	1.67
Mg[a]	4.71	0.81	1.20	1.93	2.26	2.36
Al[a]	15.06	4.49	6.20	9.28	9.77	11.72
P[a]	0.18	0.33	1.26	1.95	2.26	1.20
K[a]	1.67	0.74	0.75	1.20	1.23	1.57
Ca[a]	4.92	3.37	3.69	4.73	5.31	4.24
Mn[a]	0.11	0.06	0.06	0.07	0.08	0.07
Fe[a]	8.06	4.33	4.38	7.80	7.13	7.31
S	357	19008	26040	5375	4703	3413
Cl	270	1377	582	775	638	735
Sc	26	15	16	17	13	18
V	141	86	123	102	104	109
Cr	220	97	126	132	138	136
Ni	71	11	35	29	27	30
Cu	29	15	44	20	15	19
Zn	19	12	109	25	40	28
Ga	17	8	10	13	14	15
Rb	37.5	13.9	15.2	26.9	26.6	39.0
Sr	361.6	185.0	222.4	351.9	356.1	376.5
Y	20.6	5.9	7.7	9.2	9.2	10.7
Zr	240.5	72.8	70.8	130.0	365.8	115.0
Nb	11.4	3.0	4.0	5.0	4.9	7.2
Ba	769	892	928	1064	970	1041
Ce	74	201	212	160	116	146

a= reported in % weight of their oxide; remaining elements reported in ppm

Table A.11: ICP-MS Data for Nachvak Village

	Control	H4 Lamp Area	H4 Sleeping Platform	H4 Tunnel	H2 Midden	H10 Midden
Li	3.808	6.932	13.184	2.754	5.875	3.639
Mo	1.579	0.559	0.275	0.312	-0.111	0.700
Cs	0.248	0.320	0.267	0.082	0.255	0.161
La	33.007	35.892	29.143	22.884	28.441	15.545
Pr	6.829	7.392	6.564	4.502	6.217	3.334
Nd	22.687	25.099	24.078	15.076	21.179	11.729
Sm	2.849	3.531	4.209	1.926	2.907	1.600
Eu	0.675	0.886	1.132	0.489	0.718	0.416
Gd	1.527	2.172	3.261	1.192	1.824	1.160
Tb	0.202	0.279	0.539	0.160	0.242	0.158
Dy	1.342	1.914	3.699	1.277	1.774	1.219
Ho	0.251	0.354	0.772	0.227	0.310	0.222
Er	0.647	0.996	1.967	0.597	0.876	0.558
Tm	0.095	0.132	0.306	0.099	0.137	0.086
Yb	0.611	0.841	1.897	0.496	0.730	0.582
Lu	0.100	0.136	0.262	0.063	0.114	0.075
Hf	0.635	0.986	1.768	0.407	0.623	0.427
Ta	0.894	0.898	0.712	0.640	0.838	4.835
Ti	0.117	0.142	0.161	0.079	0.108	0.083
Pb	7.850	18.941	10.258	5.489	17.734	12.415
Th	2.857	5.782	4.534	1.787	4.207	1.550

All elements reported in ppm

Table A.12: Increased Elements for Nachvak Village

	H4 Lamp Area	H4 Platform	H4 Tunnel	H2 Midden	H10 Midden
Li	80%	249%	---	---	---
Na	---	---	---	---	---
K	---	---	---	---	---
Rb	---	---	---	---	---
Cs	30%	---	---	3%	4%
Mg	---	---	---	---	---
Ca	---	---	---	---	---
Sr	---	---	---	---	4%
Ba	10%	20%	40%	30%	40%
P	80%	600%	900%	1155%	560%
S	5200%	7200%	1400%	1200%	950%
Cl	410%	110%	180%	130%	170%
Al	---	---	---	---	---
Ti	25%	45%	---	---	---
V	---	---	---	---	---
Cr	---	---	---	---	---
Mn	---	---	---	---	---
Fe	---	---	---	---	---
Ni	---	---	---	---	---
Cu	---	50%	---	---	---
Zn	---	470%	30%	110%	---
Zr	---	---	---	50%	---
Nb	---	---	---	---	---
Mo	---	---	---	---	---
Pb	140%	30%	---	125%	60%
Ga	---	---	---	---	45%
Hf	55%	170%	---	---	---
Sc	---	---	---	---	---
Y	---	---	---	---	---
La	---	20%	---	---	---
Ce	170%	180%	110%	20%	100%
Pr	---	---	---	---	---
Nd	10%	6%	---	---	---
Sm	30%	50%	---	---	---
Eu	30%	70%	---	6%	---
Gd	40%	113%	---	20%	---
Tb	35%	165%	---	20%	---
Dy	45%	175%	---	30%	---
Ho	40%	210%	---	25%	---
Er	55%	---	---	35%	---
Tm	35%	---	4%	45%	---
Yb	35%	---	---	20%	---
Lu	35%	160%	---	13%	---
Ta	---	---	---	---	440%
Th	105%	40%	---	---	---

Table A.13: Chemical Reactivity Data for House 9, Komaktorvik 1

H9	Control	Floor	Platform	Lamp Area	Tunnel	Berm
pH	4.98	4.49	4.50	4.54	5.43	4.62
Eh[a]	255.8	287.9	269.2	231.5	224.7	274.4
TDS[b]	770	800	700	110	720	740

a–mV; b–ppm

Table A.14: XRF Data for House 9, Komaktorvik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm
Na[a]	2.44%	1.67%	2.17%	1.63%	2.57%	2.30%
Mg[a]	4.27%	2.41%	3.05%	2.63%	3.21%	3.26%
Al[a]	12.70%	10.44%	12.26%	9.93%	13.04%	12.48%
P[a]	0.11%	0.61%	0.47%	0.47%	0.29%	0.38%
K[a]	1.23%	1.15%	1.27%	1.08%	1.43%	1.25%
Ca[a]	4.83%	4.16%	4.26%	3.98%	4.36%	4.24%
Mn[a]	0.10%	0.08%	0.07%	0.08%	0.06%	0.08%
Fe[a]	6.88%	5.14%	5.38%	5.70%	4.78%	5.54%
S	469	3860	1321	2242	1125	1058
Cl	202	473	320	342	237	243
Sc	LD	16	15	13	LD	13
V	108	90	86	80	76	86
Cr	242	189	170	185	148	181
Ni	56.83	45.73	46.84	40.13	41.12	43.09
Cu	7.16	8.89	6.75	6.64	5.38	6.05
Zn	7.01	10.27	7.92	LD	LD	LD
Ga	15.54	14.59	15.85	13.39	15.93	14.78
Rb	22.74	21.59	23.83	22.15	27.30	22.73
Sr	275.30	262.81	281.48	256.47	300.32	270.34
Y	16.93	10.94	11.18	10.93	10.55	12.38
Zr	82.48	72.70	71.98	70.17	80.02	71.02
Nb	5.38	4.00	3.67	4.51	4.54	4.00
Ba	531.21	729.98	648.32	653.84	609.10	554.04
Ce	52.22	68	88	81.08	68.10	52.79

a= reported in % weight of their oxide; remaining elements reported in ppm

Table A.15: ICP-MS Data for House 9, Komaktorvik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm
Li	16.729	96.367	10.991	9.327	12.528	10.563
Rb	20.593	20.390	23.171	21.830	26.486	20.643
Sr	259.43	271.54	276.22	260.48	301.85	266.02
Y	16.577	12.038	12.403	10.785	10.848	13.099
Nb	3.820	3.733	3.764	3.292	3.747	3.612
Mo	1.772	1.416	1.525	0.762	1.470	1.525
Cs	0.111	0.140	0.148	0.250	0.161	0.124
Ba	440.02	448.55	483.45	439.62	546.54	455.96
La	17.113	16.729	16.758	15.209	16.813	16.587
Ce	33.312	31.526	31.611	27.896	31.744	30.877
Pr	4.007	3.603	3.610	3.380	3.704	3.518
Nd	14.787	13.175	12.877	12.428	13.405	12.877
Sm	2.952	2.332	2.380	2.525	2.495	2.380
Eu	0.849	0.718	0.756	0.809	0.823	0.756
Gd	3.113	2.139	2.226	2.394	2.905	2.298
Tb	0.496	0.337	0.350	0.398	0.316	0.374
Dy	3.343	2.157	2.336	2.540	2.072	2.555
Ho	0.673	0.441	0.470	0.495	0.405	0.516
Er	1.909	1.295	1.311	1.503	1.130	1.550
Tm	0.261	0.208	0.186	0.254	0.186	0.240
Yb	1.810	1.165	1.302	1.393	1.032	1.483
Lu	0.263	0.157	0.184	0.205	0.125	0.194
Hf	1.183	0.952	1.151	0.889	0.695	0.919
Ta	1.172	0.990	0.868	2.332	1.918	1.498
Ti	0.043	0.107	0.091	0.160	0.124	0.119
Pb	6.728	6.809	7.469	7.539	8.217	7.289
Th	1.629	1.992	1.701	1.497	1.810	1.638

All elements reported in ppm

Table A.16: Increased Elements for House 9, Komaktorvik 1

	Floor	Platform	Lamp Area	Tunnel	Berm
Li	---	---	---	---	---
Na	---	---	---	---	---
K	---	3%	---	---	2%
Rb	---	13%	6%	29%	---
Cs	26%	33%	125%	45%	12%
Mg	---	---	---	---	---
Ca	---	---	---	---	---
Sr	5%	7%	---	16%	3%
Ba	2%	10%	23%	24%	3%
P	454%	327%	327%	164%	245%
S	723%	182%	378%	140%	126%
Cl	134%	58%	69%	17%	20%
Al	---	---	---	---	---
Ti	149%	116%	272%	188%	177%
V	---	---	---	---	---
Cr	---	---	---	---	---
Mn	---	---	---	---	---
Fe	---	---	---	---	---
Ni	---	---	---	---	---
Cu	24%	---	---	---	---
Zn	47%	13%	---	---	---
Zr	---	---	---	---	---
Nb	---	---	---	---	---
Mo	---	---	---	---	---
Pb	1%	11%	12%	22%	8%
Ga	---	2%	---	3%	---
Hf	---	---	---	---	---
Sc	1600%	1500%	1300%	---	1300%
Y	---	---	---	---	---
La	---	---	---	---	---
Ce	31%	96%	56%	31%	1%
Pr	---	---	---	---	---
Nd	---	---	---	---	---
Sm	---	---	---	---	---
Eu	---	---	---	---	---
Gd	---	---	---	---	---
Tb	---	---	---	---	---
Dy	---	---	---	---	---
Ho	---	---	---	---	---
Er	---	---	---	---	---
Tm	---	---	---	---	---
Yb	---	---	---	---	---
Lu	---	---	---	---	---
Ta	---	---	99%	63%	---
Th	23%	5%	---	12%	1%

Table A.17: Chemical Reactivity Data for House 11, Komaktorvik 1

	Control	Floor	North Platform	South Platform	West Platform	Tunnel
pH	4.98	4.45	5.50	5.12	4.33	4.60
Eh[a]	255.8	309.8	207.2	217.0	314.2	225.1
TDS[b]	770	90	100	100	80	100

a- mV; b -ppm

Table A.18: XRF Data for House 11, Komaktorvik 1

	Control	Floor	North Platform	West Platform	South Platform	Tunnel
Na[a]	2.44%	2.32%	2.41%	2.16%	2.48%	2.56%
Mg[a]	4.27%	3.73%	3.98%	3.49%	3.43%	3.86%
Al[a]	12.70%	12.29%	12.68%	11.70%	12.65%	12.94%
P[a]	0.11%	0.22%	0.18%	0.22%	0.24%	0.22%
K[a]	1.23%	1.27%	1.31%	1.33%	1.26%	1.26%
Ca[a]	4.83%	4.27%	4.33%	4.16%	4.16%	4.22%
Mn[a]	0.10%	0.09%	0.09%	0.08%	0.08%	0.08%
Fe[a]	6.88%	6.07%	6.45%	5.92%	5.51%	5.83%
S	469	624	495	554	881	679
Cl	202	231	196	228	249	231
Sc	LD	15	16	21	13	18
V	108	95	96	91	84	83
Cr	242	189	204	188	167	179
Ni	56.83	46.33	49.05	42.75	38.91	44.24
Cu	7.16	7.47	7.58	9.57	6.52	5.86
Zn	7.01	LD	LD	6.01	LD	LD
Ga	15.54	14.20	16.31	15.80	14.74	13.20
Rb	22.74	23.29	24.54	24.41	22.41	23.71
Sr	275.30	267.33	268.23	272.14	265.25	267.58
Y	16.93	16.09	18.28	15.47	13.66	14.53
Zr	82.48	76.25	82.21	74.26	86.98	89.71
Nb	5.38	4.95	5.24	4.08	5.30	5.83
Ba	531.21	553.01	541.05	633.71	536.40	504.59
Ce	52.22	LD	LD	79.97	51.23	LD

a- reported in % weight of their oxide; remaining elements reported in ppm

Table A.19: ICP-MS Data for House 11, Komaktorvik 1

	Control	Floor	North Platform	West Platform	South Platform	Tunnel
Li	16.729	12.739	12.925	11.917	10.804	12.347
Rb	20.593	23.049	22.716	21.235	22.788	23.000
Sr	259.43	271.15	262.35	246.30	274.94	269.14
Y	16.577	17.404	18.835	15.001	14.286	14.643
Nb	3.820	3.604	3.756	3.061	3.292	3.558
Mo	1.772	0.123	0.047	0.135	0.143	0.193
Cs	0.111	0.111	0.126	0.128	0.116	0.156
Ba	440.02	458.34	440.93	434.37	500.76	499.98
La	17.113	15.172	15.050	18.824	16.935	16.852
Ce	33.312	29.204	28.643	36.595	31.755	31.440
Pr	4.007	3.400	3.492	4.402	3.735	3.665
Nd	14.787	12.874	13.345	15.704	13.389	13.888
Sm	2.952	2.509	2.882	2.936	2.413	2.703
Eu	0.849	0.791	0.812	0.747	0.763	0.827
Gd	3.113	2.881	3.137	2.793	2.479	2.656
Tb	0.496	0.493	0.532	0.438	0.393	0.434
Dy	3.343	3.285	3.572	2.955	2.694	2.814
Ho	0.673	0.697	0.733	0.583	0.549	0.574
Er	1.909	1.965	2.130	1.749	1.535	1.651
Tm	0.261	0.272	0.357	0.281	0.274	0.238
Yb	1.810	1.876	1.964	1.605	1.424	1.618
Lu	0.263	0.262	0.288	0.237	0.198	0.228
Hf	1.183	0.921	0.789	0.793	0.595	0.991
Ta	1.172	1.358	1.414	0.866	2.148	2.766
Ti	0.043	0.082	0.136	0.125	0.128	0.106
Pb	6.728	7.204	7.058	7.985	8.083	8.060
Th	1.629	1.556	1.419	2.811	1.638	1.694

All elements reported in ppm

Table A.20: Increased Elements for House 11, Komaktorvik 1

	Floor	North Platform	West Platform	South Platform	Tunnel
Li	---	---	---	---	---
Na	---	---	---	2%	5%
K	2%	7%	8%	2%	2%
Rb	16%	8%	5%	11%	15%
Cs	---	14%	15%	5%	40%
Mg	---	---	---	---	---
Ca	---	---	---	---	---
Sr	5%	1%	---	6%	4%
Ba	4%	2%	19%	14%	13%
P	100%	64%	100%	118%	100%
S	33%	6%	18%	87%	45%
Cl	14%	---	13%	23%	14%
Al	---	---	---	---	---
Ti	93%	202%	190%	198%	147%
V	---	---	---	---	---
Cr	---	---	---	---	---
Mn	---	---	---	---	---
Fe	---	---	---	---	---
Ni	---	---	---	---	---
Cu	4%	6%	34%	---	---
Zn	---	---	---	---	---
Zr	---	---	---	---	---
Nb	---	---	---	---	8%
Mo	---	---	---	---	---
Pb	7%	4%	18%	19%	2%
Ga	---	---	2%	---	---
Hf	---	---	---	---	---
Sc	1500%	1600%	2100%	1300%	1800%
Y	5%	15%	---	---	---
La	---	---	10%	---	---
Ce	---	---	10%	---	---
Pr	---	---	10%	---	---
Nd	---	---	7%	---	---
Sm	---	---	---	---	---
Eu	---	---	---	---	---
Gd	---	---	---	---	---
Tb	---	8%	---	---	---
Dy	---	6%	---	---	---
Ho	3%	9%	---	---	---
Er	---	11%	---	---	---
Tm	5%	34%	10%	4%	---
Yb	3%	3%	---	---	---
Lu	---	8%	---	---	---
Ta	23%	---	---	91%	145%
Th	---	---	75%	1%	4%

Table A.21: Chemical Reactivity Data for House 1, Komaktorvik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm	Midden
pH	4.98	4.63	4.72	4.32	5.28	4.94	5.06
Eh[a]	255.8	260.3	226.1	296.3	177.0	178.2	180.5
TDS[b]	770	120	110	100	110	90	90

a mV; b ppm

Table A.22: XRF Data for House 1, Komaktorvik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm	Midden
Na[a]	2.44%	1.34%	2.13%	1.81%	2.13%	2.09%	2.08%
Mg[a]	4.27%	1.79%	2.68%	2.15%	2.42%	2.44%	2.38%
Al[a]	12.70%	8.50%	12.39%	10.72%	11.55%	11.82%	11.67%
P[a]	0.11%	0.77%	0.51%	0.94%	0.36%	0.56%	0.72%
K[a]	1.23%	1.06%	1.40%	1.23%	1.30%	1.34%	1.33%
Ca[a]	4.83%	3.50%	3.98%	4.35%	3.84%	3.94%	3.94%
Mn[a]	0.10%	0.06%	0.06%	0.06%	0.06%	0.05%	0.05%
Fe[a]	6.88%	5.12%	4.46%	4.68%	4.26%	4.25%	4.10%
S	469	2487	1020	2043	1499	1521	1444
Cl	202	378	262	343	304	360	307
Sc	LD	9	14	12	11	16	14
V	108	72	69	69	69	68	67
Cr	242	137	134	130	131	124	128
Ni	56.83	27.96	32.42	28.28	26.86	29.96	29.45
Cu	7.16	10.42	7.88	11.4	9.93	6.34	5.00
Zn	7.01	LD	LD	LD	LD	LD	LD
Ga	15.54	12.87	13.93	12.59	14.26	13.31	14.00
Rb	22.74	23.95	26.38	22.63	24.24	24.41	24.18
Sr	275.30	268.77	295.42	277.79	280.47	282.29	295.26
Y	16.93	8.03	9.09	8.51	8.25	8.48	8.11
Zr	82.48	58.85	76.86	73.07	88.31	69.07	75.28
Nb	5.38	3.70	4.58	4.17	5.28	3.94	4.15
Ba	531.21	745.10	682.55	697.30	684.04	668.64	700.11
Ce	52.22	82.17	73.91	55.01	LD	47.75	47.97

a= reported in % weight of their oxide; remaining elements reported in ppm

Table A.23: ICP-MS Data for House 1, Komaktorvik 1

	Control	Floor	Platform	Lamp Area	Tunnel	Berm	Midden
Li	16.729	9.604	10.962	8.487	8.525	9.264	9.449
Rb	20.593	21.640	28.965	22.726	22.101	23.938	23.182
Sr	259.43	275.90	324.03	296.43	262.07	297.84	298.18
Y	16.577	8.771	10.232	9.874	8.047	9.078	9.820
Nb	3.820	2.816	2.941	3.208	3.213	3.230	3.790
Mo	1.772	0.162	0.647	0.727	0.637	0.548	0.820
Cs	0.111	0.160	0.237	0.197	0.194	0.185	0.187
Ba	440.02	491.37	576.27	512.08	450.01	489.66	568.95
La	17.113	17.142	16.206	15.981	15.555	16.947	15.838
Ce	33.312	31.996	28.332	29.071	28.331	30.360	28.463
Pr	4.007	3.633	3.391	3.347	3.403	3.516	3.304
Nd	14.787	12.761	12.351	12.426	12.541	12.606	12.125
Sm	2.952	2.152	2.321	2.271	2.292	2.157	2.233
Eu	0.849	0.715	0.885	0.817	0.770	0.789	0.833
Gd	3.113	1.716	2.026	1.957	1.730	1.828	1.973
Tb	0.496	0.275	0.324	0.305	0.257	0.271	0.308
Dy	3.343	1.729	1.934	1.865	1.700	1.685	1.864
Ho	0.673	0.336	0.384	0.372	0.328	0.331	0.380
Er	1.909	0.997	1.188	1.121	1.019	1.016	1.113
Tm	0.261	0.179	0.209	0.163	0.192	0.185	0.198
Yb	1.810	0.937	1.063	1.065	0.904	0.868	0.989
Lu	0.263	0.113	0.155	0.157	0.134	0.125	0.145
Hf	1.183	0.472	1.370	0.994	0.884	0.696	0.771
Ta	1.172	1.432	1.428	2.529	3.034	1.956	1.869
Ti	0.043	0.152	0.206	0.148	0.192	0.177	0.168
Pb	6.728	13.062	9.703	22.253	11.741	10.064	11.352
Th	1.629	1.662	1.039	1.314	2.366	1.390	1.373

All elements reported in ppm

Table A.24: Increased Elements for House 1, Komaktorvik 1

	Floor	Platform	Lamp Area	Tunnel	Berm	Midden
Li	---	---	---	---	---	---
Na	---	---	---	---	---	---
K	---	14%	---	6%	9%	8%
Rb	5%	40%	10%	10%	20%	20%
Cs	44%	114%	77%	75%	67%	---
Mg	---	---	---	---	---	---
Ca	---	---	---	---	---	---
Sr	6%	25%	14%	1%	15%	15%
Ba	12%	29%	16%	2%	11%	29%
P	600%	364%	755%	227%	409%	554%
S	403%	117%	336%	220%	224%	208%
Cl	87%	30%	70%	50%	78%	52%
Al	---	---	---	---	---	---
Ti	248%	379%	224%	342%	312%	291%
V	---	---	---	---	---	---
Cr	---	---	---	---	---	---
Mn	---	---	---	---	---	---
Fe	---	---	---	---	---	---
Ni	---	---	---	---	---	---
Cu	46%	10%	---	39%	---	---
Zn	---	---	---	---	---	---
Zr	---	---	---	---	---	---
Nb	---	---	---	---	---	---
Mo	---	---	---	---	---	---
Pb	94%	45%	231%	75%	49%	69%
Ga	---	---	---	---	---	---
Hf	---	16%	---	---	---	---
Sc	900%	1400%	1200%	1100%	1600%	1400%
Y	---	---	---	---	---	---
La	---	---	---	---	---	68%
Ce	58%	40%	6%	---	---	---
Pr	---	---	---	---	---	---
Nd	---	---	---	---	---	---
Sm	---	---	---	---	---	---
Eu	---	4%	---	---	---	---
Gd	---	---	---	---	---	---
Tb	---	---	---	---	---	---
Dy	---	---	---	---	---	---
Ho	---	---	---	---	---	---
Er	---	---	---	---	---	---
Tm	---	---	---	---	---	---
Yb	---	---	---	---	---	---
Lu	---	---	---	---	---	---
Ta	22%	22%	116%	159%	59%	59%
Th	---	---	---	44%	---	---

Table A.25: Chemical Reactivity Data for Big Head

	Control	Floor	Midden
pH	4.96	5.43	4.43
Eh[a]	283.2	280.1	223.5
TDS[b]	60	50	70

a–mV; b=ppm

Table A.26: XRF Data for Big Head

	Control	House Floor	Midden
Na[a]	1.80%	1.28%	1.43%
Mg[a]	4.62%	1.89%	2.13%
Al[a]	10.87%	7.53%	7.84%
P[a]	0.29%	1.46%	0.85%
K[a]	0.49%	0.76%	0.69%
Ca[a]	7.41%	5.07%	4.07%
Mn[a]	0.17%	0.08%	0.09%
Fe[a]	12.04%	6.65%	7.38%
S	3126	6435	6657
Cl	583	768	1351
Sc	30	18	26
V	230	97	90
Cr	222	215	245
Ni	53.59	53.48	61.73
Cu	19.38	20.24	22.29
Zn	LD	28.03	LD
Ga	17.15	10.62	8.29
As	29.73	16.60	25.04
Rb	10.47	15.66	14.59
Sr	183.16	251.67	209.70
Y	18.73	11.41	9.50
Zr	76.34	70.70	66.29
Nb	5.37	3.99	4.20
Ba	229.18	593.60	531.15
Ce	69.58	92.07	113.77

a– reported in % weight of their oxide; remaining elements reported in ppm

Table A.27: ICP-MS Data for Big Head

	Control	House Floor	Midden
Li	11.424	6.895	5.776
Rb	6.502	12.791	9.500
Sr	168.17	253.80	218.43
Y	18.771	12.063	10.429
Nb	3.653	2.509	2.638
Mo	0.155	0.128	LD
Cs	0.019	0.152	0.157
Ba	123.38	270.15	225.22
La	8.506	14.164	12.710
Ce	18.519	26.069	23.524
Pr	2.426	3.118	2.883
Nd	10.018	11.328	10.079
Sm	2.306	1.797	1.689
Eu	0.681	0.561	0.463
Gd	3.000	1.786	1.495
Tb	0.501	0.293	0.236
Dy	3.558	2.100	1.729
Ho	0.725	0.410	0.325
Er	2.087	1.152	0.928
Tm	0.283	0.178	0.145
Yb	1.921	0.921	0.728
Lu	0.275	0.128	0.083
Hf	0.742	0.172	0.273
Ta	1.730	0.573	1.142
Ti	LD	0.004	0.005
Pb	3.802	5.239	5.009
Th	1.570	1.531	1.472

All elements reported in ppm

Table A.28: Increased Elements at Big Head

	Floor	Midden
Li	---	---
Na	---	---
K	55%	41%
Rb	97%	46%
Cs	700%	726%
Mg	---	---
Ca	---	---
Sr	51%	30%
Ba	119%	83%
P	403%	193%
S	106%	113%
Cl	23%	132%
Al	---	---
Ti	40%	50%
V	---	---
Cr	---	---
Mn	---	---
Fe	---	---
Ni	---	15%
Cu	4%	15%
Zn	280%	---
Zr	---	---
Nb	---	---
Mo	---	---
Pb	38%	32%
Ga	---	---
Hf	---	---
Sc	---	---
Y	---	---
La	67%	49%
Ce	41%	27%
Pr	29%	19%
Nd	13%	---
Sm	---	---
Eu	---	---
Gd	---	---
Tb	---	---
Dy	---	---
Ho	---	---
Er	---	---
Tm	---	---
Yb	---	---
Lu	---	---
Ta	---	---
Th	---	---

APPENDIX B:

STATISTICAL DATA

Table B.1: Kolmogorov-Smirnov Normality Test for pH, Eh, and TDS

	Kolmogorov-Smirnov	Significance
pH	0.143	0.049
Eh	0.101	0.200
TDS	0.342	0.000

Table B.2: Kolmogorov-Smirnov Normality Test for 45 Elements

Element	Kolmogorov-Smirnov	Significance	Element	Kolmogorov-Smirnov	Significance
Li	0.149	0.033	Mo	0.188	0.002
Na	0.104	0.200	Pb	0.193	0.001
K	0.286	0.000	Ga	0.084	0.200
Rb	0.280	0.000	Hf	0.137	0.070
Cs	0.181	0.003	Sc	0.185	0.002
Mg	0.152	0.027	Y	0.167	0.009
Ca	0.143	0.048	La	0.216	0.000
Sr	0.129	0.108	Ce	0.246	0.000
Ba	0.243	0.000	Pr	0.206	0.000
P	0.229	0.000	Nd	0.193	0.001
S	0.272	0.000	Sm	0.120	0.187
Cl	0.254	0.000	Eu	0.253	0.000
Al	0.160	0.015	Gd	0.115	0.200
Ti	0.179	0.004	Tb	0.113	0.200
V	0.139	0.062	Dy	0.150	0.030
Cr	0.182	0.003	Ho	0.148	0.036
Mn	0.397	0.000	Er	0.139	0.062
Fe	0.120	0.179	Tm	0.150	0.030
Ni	0.149	0.033	Yb	0.149	0.033
Cu	0.151	0.029	Lu	0.143	0.050
Zn	0.416	0.000	Ta	0.182	0.003
Zr	0.200	0.001	Th	0.174	0.005
Nb	0.268	0.000			

Table B.3: Skewness and Kurtosis Statistics for pH, Eh, and TDS

	Skewness[1]	Kurtosis[2]
pH	0.453	-0.836
Eh	-0.045	-0.989
TDS	1.015	-0.752

1=Std Error 0.383 2=Std Error 0.750

Table B.4: Skewness and Kurtosis Statistics for 45 Elements

Element	Skewness[1]	Kurtosis[2]	Element	Skewness	Kurtosis
Li	5.583	32.061	Mo	0.228	-1.294
Na	-0.498	-0.319	Pb	0.289	-1.313
K	0.660	-1.389	Ga	-0.606	0.205
Rb	0.674	-1.431	Hf	0.537	-0.048
Cs	0.457	-1.509	Sc	-0.527	-0.669
Mg	0.278	-1.226	Y	1.015	1.758
Ca	-0.144	-1.065	La	1.795	3.075
Sr	-0.068	1.363	Ce	2.338	4.329
Ba	0.392	-1.593	Pr	1.683	2.388
P	1.914	3.376	Nd	1.560	1.985
S	3.468	12.551	Sm	0.958	1.720
Cl	2.378	5.570	Eu	0.453	-1.206
Al	-1.158	1.021	Gd	0.226	0.010
Ti	0.413	-1.232	Tb	0.491	0.622
V	-0.294	-1.263	Dy	0.845	0.727
Cr	- 0.224	-1.276	Ho	0.964	1.063
Mn	5.799	33.742	Er	0.642	0.610
Fe	0.156	-1.059	Tm	0.693	1.322
Ni	-0.116	-1.279	Yb	0.679	0.178
Cu	1.895	5.521	Lu	0.623	0.299
Zn	3.999	18.373	Ta	2.127	6.278
Zr	3.629	16.484	Th	2.019	4.618
Nb	1.050	-0.198			

1=Std Error 0.403 2=Std Error 0.788

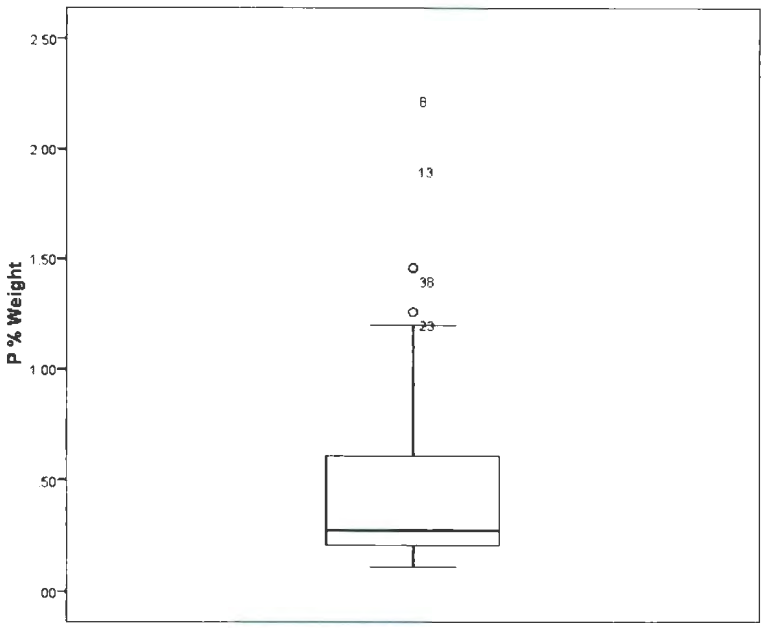

Figure B.1: Box and Whisker Plot Showing Potential Outliers for P

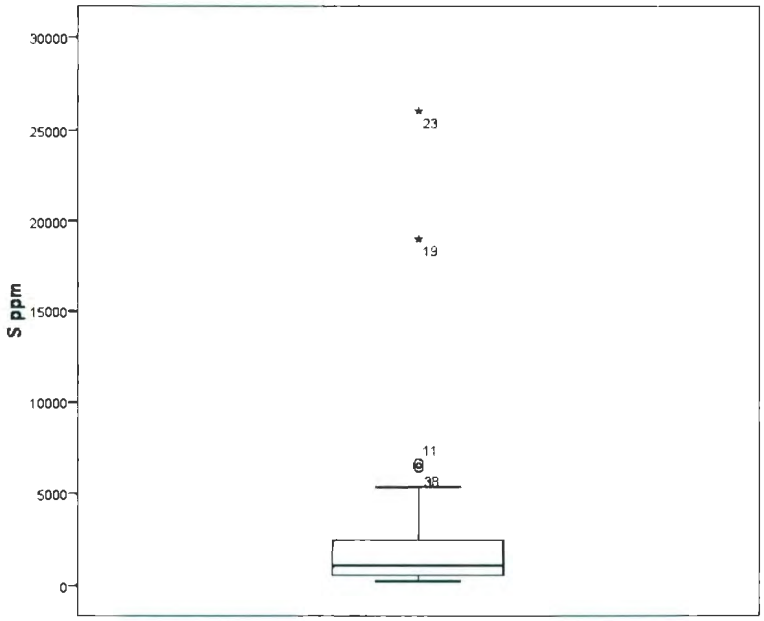

Figure B.2: Box and Whisker Plot Showing Potential Outliers for S

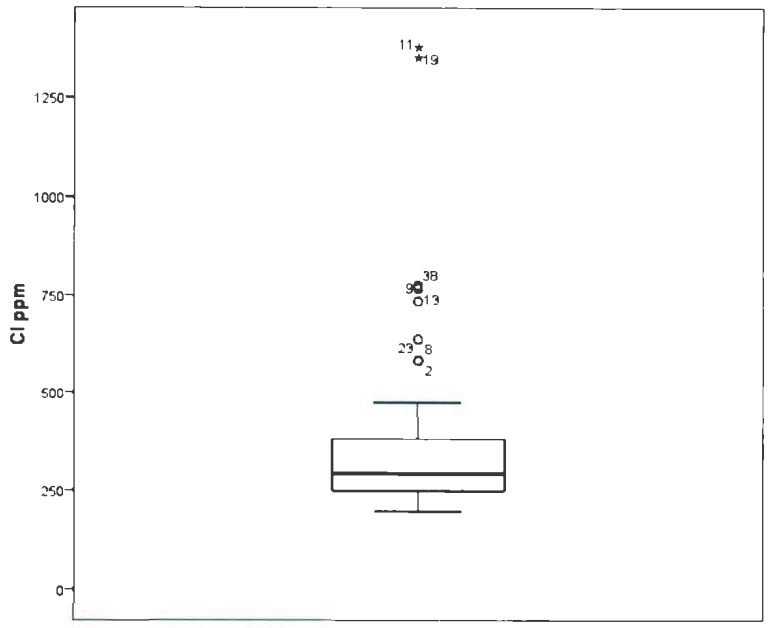

Figure B.3: Box and Whisker Plot Showing Potential Outliers for Cl

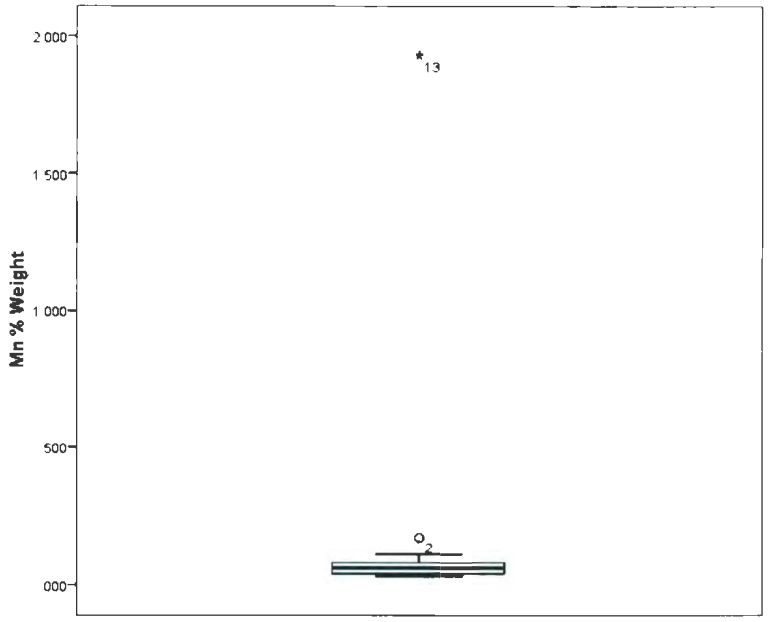

Figure B.4: Box and Whisker Plot Showing Potential Outliers for Mn

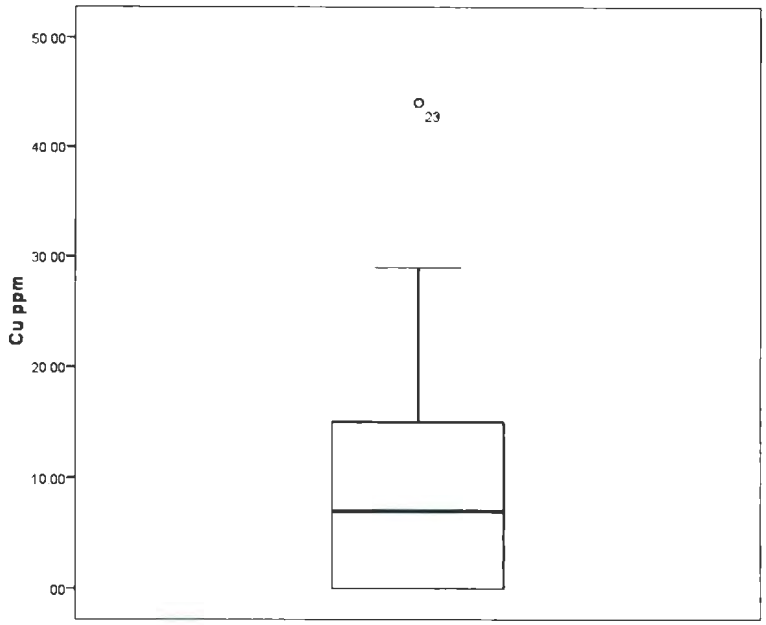

Figure B.5: Box and Whisker Plot Showing Potential Outliers for Cu

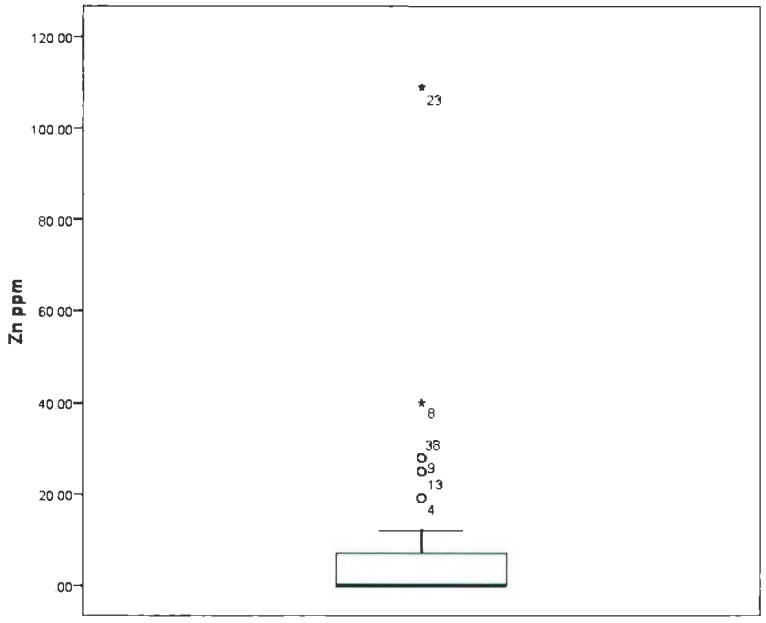

Figure B.6: Box and Whisker Plot Showing Potential Outliers for Zn

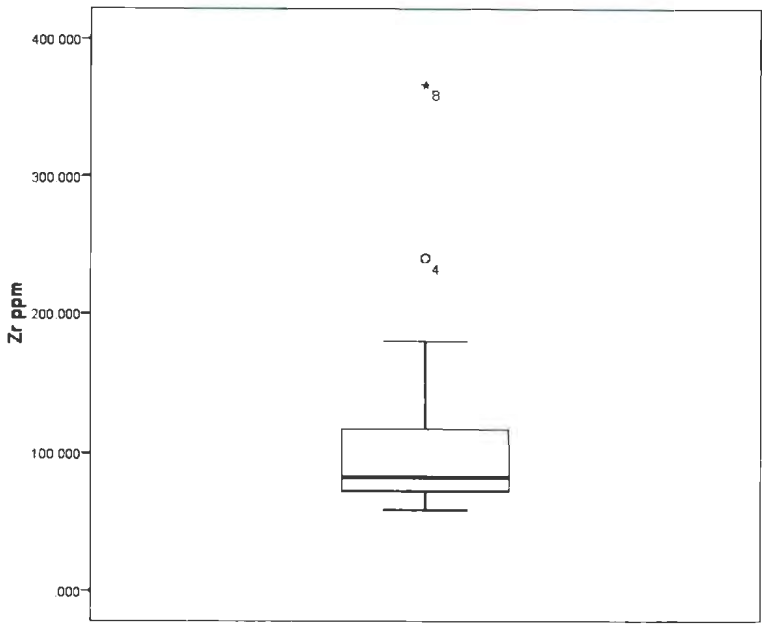

Figure B.7: Box and Whisker Plot Showing Potential Outliers for Zr

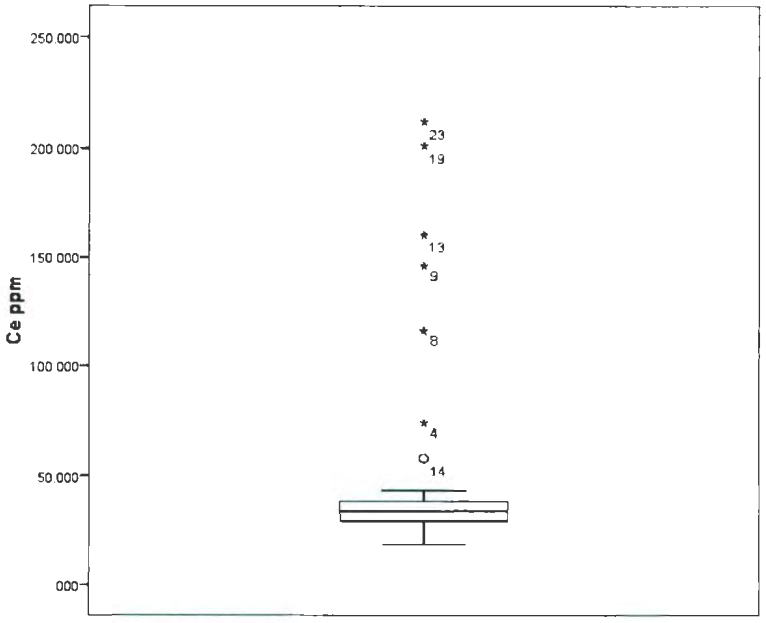

Figure B.8: Box and Whisker Plot Showing Potential Outliers for Ce

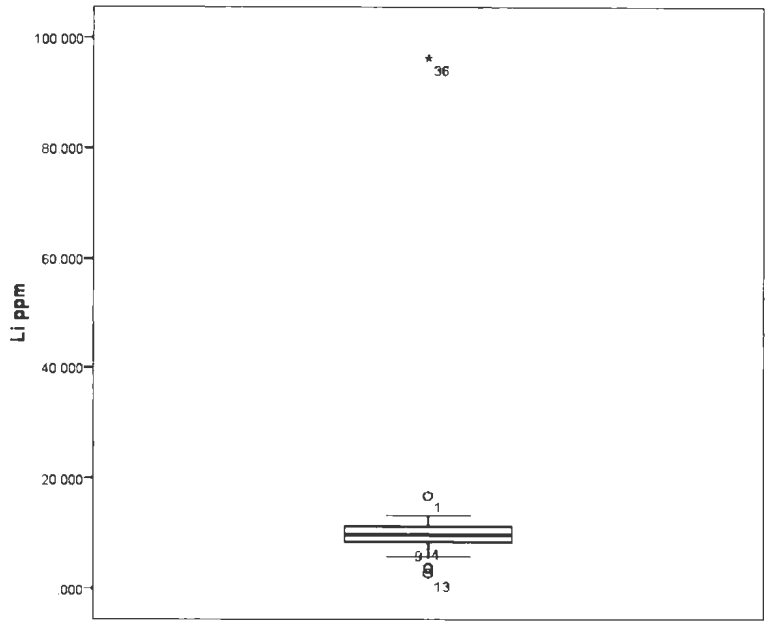

Figure B.9: Box and Whisker Plot Showing Potential Outliers for Li

Table B.5: Recoded Outlier Cases

Element	Sample	Original Value	Modified Value
P	Nachvak H4 Tunnel	1.95	1.50
	Nachvak H2 Midden	2.26	1.60
S	Nachvak H4 Lamp Area	19008	7000
	Nachvak H4 Platform	26040	8000
Cl	Nachvak H4 Lamp Area	1377	850
	Big Head Midden	1351	800
Mn	Nachvak H4 Tunnel	1.930	1.00
Cu	Nachvak H4 Platform	44	24
Zn	Nachvak H2 Midden	40	28
	Nachvak H10 Midden	28.00	26
	Nachvak H4 Platform	140	30
	Big Head H3 Floor	28.03	27
Zr	Nachvak H2 Midden	365.8	150
Ce	Nachvak H4 Tunnel	160	60
	Nachvak H2 Midden	116	59
	Nachvak H10 Midden	146	58
	Nachvak H4 Lamp Area	201	61
	Nachvak H4 Platform	212	62
Li	Komaktorvik H9 Floor	96.367	14

Table B.6: Comparison of Control and On Site Means for pH, Eh, and TDS

Context	n	pH	Eh[a]	TDS[b]	Site	n	pH	Eh	TDS
Floor	7	4.74	268.0	392	Iglosiatik	12	4.76	248.3	408
Platform	9	4.91	238.4	168	Nachvak	6	4.92	222.1	110
Lamp Area	4	4.52	250.9	280	Komaktorvik	17	4.79	243.2	290
Alcove	1	4.62	256.4	530	Big Head	3	4.94	262.2	60
Tunnel	6	4.80	237.8	308					
Berm	3	4.59	247.0	493					
Midden	4	4.79	213.6	92					
Control	4	5.28	232.4	262					

a=mV b–ppm

Table B.7: Independent-Samples T-Test for pH, Eh, and TDS

	Equal Variances	Levene's Test		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
pH	Assumed	.050	.824	2.441	36	.020	.51969	.21286	.08799	.95139
	Not assumed			2.594	3.869	.062	.51969	.20037	-.04415	1.08353
Eh	Assumed	.159	.693	-.565	36	.576	-11.7750	20.8405	-54.0414	30.4914
	Not assumed			-.496	3.531	.649	-11.7750	23.7499	-81.3167	57.7667
TDS	Assumed	.001	.977	-.132	36	.896	-20.441	155.184	-335.169	294.286
	Not Assumed			-.116	3.532	.914	-20.441	176.722	-537.832	496.949

Table B.8: Comparison of Control and On Site Means for 45 Elements

Element	Control[1]	On Site[2]	Element	Control	On Site
Li	10.6175	11.9747	Mo	0.8765	0.9500
Na[a]	2.5000	2.1938	Pb	9.1310	11.8858
K[a]	1.7425	1.8147	Ga	16.4275	14.8876
Rb	34.8892	38.1876	Hf	0.8505	1.0540
Cs	0.18275	0.2585	Sc	14.00	11.59
Mg[a]	3.5975	2.0074	Y	16.4320	11.1475
Ca[a]	4.9400	3.6859	La	19.6302	19.1735
Sr	273.3900	284.8505	Ce	40.8055	53.0622
Ba	721.5800	869.3247	Pr	4.3867	4.1578
P[a]	0.1775	0.5509	Nd	15.7657	15.0077
S	1053.50	2988.94	Sm	2.6680	2.5911
Cl	319.75	414.85	Eu	0.9070	0.9799
Al[a]	13.2350	11.7032	Gd	2.3982	2.1728
Ti	0.1242	0.1988	Tb	0.3705	0.3325
V	127.00	67.44	Dy	2.5385	2.2232
Cr	179.00	115.76	Ho	0.5007	0.4365
Mn[a]	0.1025	0.1164	Er	1.4082	1.2476
Fe[a]	7.3325	4.6308	Tm	0.1977	0.1986
Ni	45.3550	26.3271	Yb	1.2885	1.1452
Cu	13.8850	8.6597	Lu	0.1847	0.1597
Zn	6.5025	7.8303	Ta	1.2470	1.5241
Zr	124.9750	101.9014	Th	2.0912	2.1845
Nb	6.6575	5.2173			

a = reported in % weight of their oxide; remaining elements reported in ppm
1 (n=4) 2 =(n 34)

Table B.9: Independent-Samples T-Test for 45 Elements Across All Sites

	Equal Variances	*Levene's Test*		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Na	Assumed	.850	.363	.804	36	.427	.30618	.38100	-.46653	1.07889
	Not Assumed			.978	4.248	.381	.30618	.31314	-.54359	1.15594
Mg	Assumed	2.560	.118	2.591	36	.014	1.59015	.61366	.34559	2.83471
	Not Assumed			1.659	3.233	.189	1.59015	.95842	-1.33930	4.51960
Al	Assumed	.321	.575	1.175	36	.248	1.53176	1.30355	-1.11196	4.17549
	Not Assumed			1.495	4.412	.203	1.53176	1.02455	-1.21117	4.27470
P	Assumed	4.630	.038	-1.561	36	.127	-.34074	.21831	-.78348	.10201
	Not Assumed			-4.050	28.150	.000	-.34074	.08413	-.51303	-.16844
S	Assumed	.947	.337	-.925	36	.361	-1051.676	1136.368	-3356.338	1252.985

	Not Assumed			-1.333	5.020	.240	-1051.676	788.799	-3076.884	973.531
Cl	Assumed	.090	.766	-.622	36	.538	-63.397	101.954	-270.170	143.376
	Not Assumed			-.668	3.894	.542	-63.397	94.920	-329.779	202.985
K	Assumed	.105	.747	-.142	36	.888	-.07221	.50933	-1.10517	.96076
	Not Assumed			-.125	3.537	.907	-.07221	.57795	-1.76319	1.61878
Ca	Assumed	3.489	.070	2.466	36	.019	1.25412	.50861	.22261	2.28563
	Not Assumed			1.264	3.121	.293	1.25412	.99254	-1.83616	4.34439
Sc	Assumed	14.347	.001	.540	36	.592	2.412	4.465	-6.643	11.467
	Not Assumed			.293	3.145	.788	2.412	8.221	-23.079	27.903
V	Assumed	8.960	.005	2.970	36	.005	59.559	20.056	18.883	100.234
	Not Assumed			1.420	3.097	.248	59.559	41.935	-71.570	190.688
Cr	Assumed	.439	.512	1.623	36	.113	63.235	38.961	-15.780	142.251
	Not Assumed			1.246	3.377	.292	63.235	50.735	-88.491	214.962
Mn	Assumed	.044	.835	.162	36	.872	.013382	.082482	-.153899	.180664
	Not Assumed			.335	10.439	.744	.013382	.039942	-.075109	.101874
Fe	Assumed	5.149	.029	2.597	36	.014	2.701618	1.040095	.592207	4.811029
	Not Assumed			1.341	3.124	.269	2.701618	2.014535	-3.567507	8.970742
Ni	Assumed	1.554	.221	1.796	36	.081	19.02794	10.59482	-2.45935	40.51523
	Not Assumed			1.196	3.259	.311	19.02794	15.91054	-29.40329	67.45918
Cu	Assumed	3.869	.057	1.395	36	.172	5.81353	4.16764	-2.63883	14.26589
	Not Assumed			.887	3.229	.436	5.81353	6.55299	-14.22949	25.85655
Zn	Assumed	.090	.766	.271	36	.788	1.40750	5.19516	-9.12877	11.94377
	Not Assumed			.294	3.916	.784	1.40750	4.79256	-12.01176	14.82676
Ga	Assumed	3.235	.080	1.053	36	.299	1.53985	1.46201	-1.42524	4.50494
	Not Assumed			2.453	16.648	.026	1.53985	.62780	.21317	2.86653
Rb	Assumed	.002	.961	-.255	36	.800	-3.298426	12.929431	-29.520529	22.923676
	Not Assumed			-.215	3.479	.842	-3.298426	15.343747	-48.538913	41.942060
Sr	Assumed	4.924	.033	-.503	36	.618	-11.460588	22.791753	-57.684407	34.763230
	Not Assumed			-.277	3.152	.799	-11.460588	41.340175	-139.501516	116.580339
Y	Assumed	2.016	.164	3.493	36	.001	5.284500	1.512694	2.216613	8.352387
	Not Assumed			2.195	3.221	.110	5.284500	2.407431	-2.087706	12.656706
Zr	Assumed	10.482	.003	1.515	36	.138	29.420588	19.414969	-9.954793	68.795970
	Not Assumed			.751	3.109	.506	29.420588	39.198253	-92.892473	151.733649
Ba	Assumed	.004	.947	-.571	36	.571	-147.74470	258.71149	-672.435930	376.946518
	Not Assumed			-.465	3.438	.670	-147.74470	317.84172	-1090.11372	794.624314
Ce	Assumed	3.639	.064	.515	36	.610	3.478559	6.755392	-10.222011	17.179128
	Not Assumed			.291	3.164	.789	3.478559	11.942351	-33.435358	40.392476
Pb	Assumed	.003	.957	-1.019	36	.315	-2.754882	2.704456	-8.239773	2.730008
	Not Assumed			-.851	3.468	.450	-2.754882	3.238758	-12.318491	6.808726
Li	Assumed	2.336	.135	.693	36	.493	1.065294	1.537424	-2.052746	4.183335
	Not Assumed			.396	3.170	.717	1.065294	2.688503	-7.237551	9.368139
Nb	Assumed	.819	.371	.982	36	.333	1.440118	1.466171	-1.533414	4.413650

	Not Assumed			.758	3.382	.498	1.440118	1.899665	-4.236924	7.117160
Mo	Assumed	.945	.337	-.187	36	.853	-.073500	.393662	-.871884	.724884
	Not Assumed			-.153	3.446	.887	-.073500	.480464	-1.496561	1.349561
Cs	Assumed	.000	1.000	-1.071	36	.291	-.075750	.070720	-.219177	.067677
	Not Assumed			-.982	3.594	.387	-.075750	.077136	-.299797	.148297
La	Assumed	2.342	.135	.150	36	.881	.456750	3.040126	-5.708912	6.622412
	Not Assumed			.089	3.186	.935	.456750	5.152047	-15.412035	16.325535
Pr	Assumed	1.182	.284	.374	36	.710	.228868	.611431	-1.011172	1.468907
	Not Assumed			.246	3.251	.820	.228868	.929708	-2.604932	3.062667
Nd	Assumed	.375	.544	.376	36	.709	.757985	2.015817	-3.330282	4.846252
	Not Assumed			.282	3.355	.794	.757985	2.687306	-7.304605	8.820575
Sm	Assumed	.823	.370	.267	36	.791	.076853	.287443	-.506108	.659814
	Not Assumed			.440	6.079	.675	.076853	.174689	-.349261	.502967
Eu	Assumed	.481	.492	-.382	36	.705	-.072912	.190876	-.460027	.314204
	Not Assumed			-.389	3.781	.718	-.072912	.187243	-.604901	.459078
Gd	Assumed	3.033	.090	.811	36	.423	.225368	.277998	-.338437	.789173
	Not Assumed			.564	3.291	.609	.225368	.399710	-.985358	1.436094
Tb	Assumed	4.527	.040	.757	36	.454	.037941	.050121	-.063709	.139591
	Not Assumed			.491	3.242	.655	.037941	.077220	-.197754	.273636
Dy	Assumed	6.573	.015	.942	36	.352	.315265	.334550	-.363235	.993764
	Not Assumed			.573	3.202	.604	.315265	.549897	-1.373839	2.004368
Ho	Assumed	6.011	.019	.874	36	.388	.064162	.073441	-.084784	.213107
	Not Assumed			.540	3.211	.625	.064162	.118866	-.300428	.428752
Er	Assumed	7.517	.009	.768	36	.447	.160632	.209047	-.263335	.584600
	Not Assumed			.453	3.185	.680	.160632	.354780	-.932261	1.253526
Yb	Assumed	7.150	.011	.689	36	.495	.143294	.207854	-.278254	.564842
	Not Assumed			.419	3.202	.702	.143294	.341941	-.907121	1.193709
Lu	Assumed	7.001	.012	.822	36	.416	.025015	.030431	-.036702	.086732
	Not Assumed			.505	3.208	.646	.025015	.049528	-.126980	.177009
Hf	Assumed	2.368	.133	-.787	36	.437	-.203529	.258689	-.728175	.321117
	Not Assumed			-1.385	6.893	.209	-.203529	.146984	-.552184	.145125
Ta	Assumed	1.321	.258	-.645	36	.523	-.277176	.429576	-1.148396	.594044
	Not Assumed			-1.222	8.152	.256	-.277176	.226737	-.798339	.243986
Tm	Assumed	3.119	.086	-.029	36	.977	-.000897	.031140	-.064051	.062257
	Not Assumed			-.020	3.277	.985	-.000897	.045643	-.139458	.137664
Ti	Assumed	.003	.956	-1.142	36	.261	-.074603	.065354	-.207146	.057941
	Not Assumed			-.960	3.476	.399	-.074603	.077739	-.303902	.154696
Th	Assumed	.436	.513	-.181	36	.858	-.093250	.516408	-1.140573	.954073
	Not Assumed			-.266	5.161	.801	-.093250	.350556	-.985978	.799478

Table B.10: Comparison of Control and On Site Elemental Means for Iglosiatik

Element	Control[1]	On Site[2]	Element	Control	On Site
Li	10.509	9.571	Mo	0.0	1.7
Na[a]	3.20	2.96	Pb	18.144	17.118
K[a]	3.31	3.13	Ga	16.02	17.95
Rb	74.962	71.511	Hf	0.842	1.572
Cs	0.353	0.434	Sc	0.0	5.0
Mg[a]	0.79	0.84	Y	9.78	10.78
Ca[a]	2.6	2.6	La	19.895	20.956
Sr	304.36	296.94	Ce	37.391	39.243
Ba	1553.92	1488.16	Pr	4.285	4.568
P[a]	0.13	0.20	Nd	15.571	16.629
S	262.0	649.1	Sm	2.565	2.859
Cl	224.0	288.6	Eu	1.423	1.458
Al[a]	14.31	14.00	Gd	1.953	2.168
Ti	0.337	0.359	Tb	0.283	0.326
V	29.0	27.3	Dy	1.911	2.192
Cr	32.0	23.9	Ho	0.354	0.420
Mn[a]	0.03	0.041	Er	0.99	1.18
Fe[a]	2.35	2.66	Tm	0.152	0.186
Ni	0.0	3.1	Yb	0.812	1.085
Cu	0.0	1.5	Lu	0.101	0.151
Zn	0.0	0.0	Ta	1.192	1.252
Zr	100.58	123.32	Th	2.309	2.410
Nb	7.757	8.502			

a= reported in % weight of their oxide; remaining elements reported in ppm
1=(n=1) 2=(n=11)

Table B.11: Independent-Samples T-Test for 45 Elements At Iglosiatik

	Equal Variances	Levene's Test		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Na	Assumed	2.569	.137	-1.299	11	.220	-.23455	.18050	-.63182	.16273
	Not Assumed			-3.159	10.000	.010	-.23455	.07425	-.39999	-.06910
Mg	Assumed	2.213	.165	.555	11	.590	.05545	.09992	-.16448	.27539
	Not Assumed			1.349	10.000	.207	.05545	.04111	-.03614	.14705
Al	Assumed	4.739	.052	-.734	11	.478	-.30818	.41992	-1.23243	.61606
	Not Assumed			-1.784	10.000	.105	-.30818	.17275	-.69309	.07672
P	Assumed	3.722	.080	3.039	11	.011	.07545	.02483	.02081	.13010
	Not Assumed			7.388	10.000	.000	.07545	.01021	.05270	.09821
S	Assumed	2.045	.180	1.659	11	.125	387.091	233.294	-126.385	900.567

	Not Assumed			4.033	10.000	.002	387.091	95.972	173.253	600.929
Cl	Assumed	2.003	.185	2.109	11	.059	64.636	30.649	-2.822	132.094
	Not Assumed			5.127	10.000	.000	64.636	12.608	36.543	92.729
K	Assumed	1.731	.215	-1.985	11	.073	-.17455	.08791	-.36804	.01895
	Not Assumed			-4.826	10.000	.001	-.17455	.03617	-.25513	-.09396
Ca	Assumed	2.427	.148	.597	11	.563	.05000	.08376	-.13435	.23435
	Not Assumed			1.451	10.000	.177	.05000	.03446	-.02677	.12677
Sc	Assumed	5.775	.035	.899	11	.388	5.000	5.563	-7.243	17.243
	Not Assumed			2.185	10.000	.054	5.000	2.288	-.099	10.099
V	Assumed	5.590	.038	-.484	11	.638	-1.636	3.379	-9.074	5.801
	Not Assumed			-1.177	10.000	.266	-1.636	1.390	-4.734	1.461
Cr	Assumed	3.316	.096	-1.360	11	.201	-8.091	5.949	-21.186	5.004
	Not Assumed			-3.306	10.000	.008	-8.091	2.447	-13.544	-2.638
Mn	Assumed	1.119	.313	1.151	11	.274	.011818	.010271	-.010787	.034424
	Not Assumed			2.797	10.000	.019	.011818	.004225	.002404	.021232
Fe	Assumed	4.265	.063	1.453	11	.174	.311818	.214583	-.160476	.784113
	Not Assumed			3.532	10.000	.005	.311818	.088275	.115130	.508506
Ni	Assumed	11.614	.006	1.337	11	.208	3.16273	2.36575	-2.04425	8.36970
	Not Assumed			3.250	10.000	.009	3.16273	.97321	.99427	5.33118
Cu	Assumed	.836	.380	.411	11	.689	1.50545	3.65955	-6.54917	9.56008
	Not Assumed			1.000	10.000	.341	1.50545	1.50545	-1.84891	4.85982
Ga	Assumed	4.048	.069	2.939	11	.013	1.93636	.65878	.48640	3.38632
	Not Assumed			7.145	10.000	.000	1.93636	.27101	1.33253	2.54020
Rb	Assumed	3.391	.093	-1.584	11	.141	-3.450182	2.177735	-8.243344	1.342980
	Not Assumed			-3.851	10.000	.003	-3.450182	.895869	-5.446303	-1.454061
Sr	Assumed	2.216	.165	-.835	11	.421	-7.419091	8.880162	-26.964197	12.126015
	Not Assumed			-2.031	10.000	.070	-7.419091	3.653092	-15.558686	.720505
Y	Assumed	9.793	.010	1.234	11	.243	1.007182	.815994	-.788808	2.803172
	Not Assumed			3.000	10.000	.013	1.007182	.335681	.259239	1.755125
Zr	Assumed	2.022	.183	1.111	11	.290	22.740000	20.463036	-22.298838	67.778838
	Not Assumed			2.701	10.000	.022	22.740000	8.418016	3.983493	41.496507
Ba	Assumed	1.910	.194	-1.184	11	.261	-65.753636	55.537352	-187.990523	56.483250
	Not Assumed			-2.878	10.000	.016	-65.753636	22.846771	-116.659415	-14.847858
Ce	Assumed	1.548	.239	.375	11	.715	1.852545	4.939430	-9.019067	12.724158
	Not Assumed			.912	10.000	.383	1.852545	2.031966	-2.674958	6.380049
Pb	Assumed	4.085	.068	-1.290	11	.223	-1.025273	.794738	-2.774479	.723933
	Not Assumed			-3.136	10.000	.011	-1.025273	.326937	-1.753733	-.296813
Li	Assumed	2.383	.151	-1.192	11	.258	-.937364	.786636	-2.668737	.794010
	Not Assumed			-2.897	10.000	.016	-.937364	.323604	-1.658397	-.216330
Nb	Assumed	3.518	.087	.512	11	.619	.745455	1.455026	-2.457036	3.947945
	Not Assumed			1.245	10.000	.241	.745455	.598564	-.588229	2.079138
Mo	Assumed	2.724	.127	8.246	11	.000	1.767818	.214389	1.295951	2.239685

	Not Assumed			20.045	10.000	.000	1.767818	.088195	1.571308	1.964328
Cs	Assumed	3.007	.111	5.425	11	.000	.081091	.014947	.048193	.113989
	Not Assumed			13.188	10.000	.000	.081091	.006149	.067390	.094791
La	Assumed	1.540	.240	.371	11	.718	1.061545	2.862391	-5.238536	7.361627
	Not Assumed			.902	10.000	.389	1.061545	1.177521	-1.562135	3.685226
Pr	Assumed	1.398	.262	.508	11	.621	.283636	.557950	-.944403	1.511675
	Not Assumed			1.236	10.000	.245	.283636	.229527	-.227783	.795055
Nd	Assumed	1.613	.230	.547	11	.595	1.058455	1.934124	-3.198524	5.315433
	Not Assumed			1.330	10.000	.213	1.058455	.795654	-.714372	2.831281
Sm	Assumed	2.259	.161	.917	11	.379	.294909	.321727	-.413206	1.003024
	Not Assumed			2.228	10.000	.050	.294909	.132351	.000013	.589805
Eu	Assumed	8.255	.015	.534	11	.604	.035273	.066070	-.110146	.180691
	Not Assumed			1.298	10.000	.224	.035273	.027180	-.025287	.095833
Gd	Assumed	5.583	.038	1.010	11	.334	.215182	.213011	-.253653	.684016
	Not Assumed			2.456	10.000	.034	.215182	.087628	.019935	.410429
Tb	Assumed	6.343	.029	1.400	11	.189	.043818	.031290	-.025051	.112687
	Not Assumed			3.404	10.000	.007	.043818	.012872	.015138	.072499
Dy	Assumed	11.926	.005	1.353	11	.203	.281818	.208333	-.176720	.740356
	Not Assumed			3.288	10.000	.008	.281818	.085703	.090859	.472777
Ho	Assumed	10.152	.009	1.784	11	.102	.066909	.037508	-.015645	.149463
	Not Assumed			4.336	10.000	.001	.066909	.015430	.032529	.101289
Er	Assumed	9.942	.009	1.809	11	.098	.198364	.109642	-.042957	.439684
	Not Assumed			4.398	10.000	.001	.198364	.045104	.097865	.298862
Yb	Assumed	12.789	.004	2.923	11	.014	.273818	.093683	.067624	.480013
	Not Assumed			7.105	10.000	.000	.273818	.038539	.187948	.359688
Lu	Assumed	5.902	.033	3.012	11	.012	.050182	.016661	.013510	.086853
	Not Assumed			7.321	10.000	.000	.050182	.006854	.034910	.065454
Hf	Assumed	3.961	.072	2.713	11	.020	.730636	.269346	.137810	1.323463
	Not Assumed			6.594	10.000	.000	.730636	.110803	.483753	.977520
Ta	Assumed	3.030	.110	.304	11	.767	.060545	.199408	-.378348	.499439
	Not Assumed			.738	10.000	.477	.060545	.082032	-.122232	.243323
Tm	Assumed	3.087	.107	3.305	11	.007	.034273	.010371	.011447	.057099
	Not Assumed			8.033	10.000	.000	.034273	.004266	.024767	.043779
Ti	Assumed	2.044	.181	1.376	11	.196	.022818	.016577	-.013668	.059305
	Not Assumed			3.346	10.000	.007	.022818	.006820	.007623	.038013
Th	Assumed	4.223	.064	.319	11	.756	.101000	.317106	-.596945	.798945
	Not Assumed			.774	10.000	.457	.101000	.130450	-.189661	.391661

Table B.12: Comparison of Control and On Site Elemental Means for Nachvak

Element	Control[1]	On Site[2]	Element	Control	On Site
Li	3.808	6.476	Mo	1.579	0.36920
Na[a]	2.56	1.0820	Pb	7.85	10.33560
K[a]	1.67	1.0980	Ga	17.0	12.0000
Rb	37.500	24.320	Hf	0.635	0.84220
Cs	0.248	0.21700	Sc	26	15.80
Mg[a]	4.71	1.6040	Y	20.6	8.54
Ca[a]	4.92	4.2680	La	33.007	26.381
Sr	361.60	298.38	Ce	74.0	167.0
Ba	769.0	979.0	Pr	6.829	5.601
P[a]	0.18	1.4000	Nd	22.687	19.432
S	357	11707	Sm	2.849	2.834
Cl	270.0	821.40	Eu	0.675	0.72820
Al[a]	15.06	8.2920	Gd	1.527	1.92180
Ti	0.117	0.11460	Tb	0.202	0.27560
V	141.0	104.80	Dy	1.342	1.97660
Cr	220.0	125.80	Ho	0.251	0.37700
Mn[a]	0.110	0.44000	Er	0.647	0.99880
Fe[a]	8.06	6.19000	Tm	0.095	0.15200
Ni	71.00	26.4000	Yb	0.611	0.90920
Cu	29.00	22.6000	Lu	0.100	0.13000
Zn	19.00	42.8000	Ta	0.894	1.58460
Zr	240.5	150.88	Th	2.857	3.57200
Nb	11.4	4.82			

a= reported in % weight of their oxide; remaining elements reported in ppm
1 = (n−1) 2=(n =5)

Table B.13: Independent-Samples T-Test for 45 Elements At Nachvak

	Equal Variances	Levene's Test		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Na	Assumed	8.030	.037	-3.898	5	.011	-1.47800	.37920	-2.45276	-.50324
	Not Assumed			-6.522	4.000	.003	-1.47800	.22661	-2.10718	-.84882
Mg	Assumed	9.250	.029	-6.117	5	.002	-3.10600	.50773	-4.41115	-1.80085
	Not Assumed			-10.237	4.000	.001	-3.10600	.30342	-3.94844	-2.26356
Al	Assumed	6.670	.049	-3.114	5	.026	-6.76800	2.17350	-12.35515	-1.18085
	Not Assumed			-5.211	4.000	.006	-6.76800	1.29891	-10.37436	-3.16164
P	Assumed	1.899	.227	2.657	5	.045	.99800	.37567	.03230	1.96370
	Not Assumed			4.445	4.000	.011	.99800	.22451	.37466	1.62134
S	Assumed	5.080	.074	3.913	5	.011	5341.200	1365.063	1832.193	8850.207

	Not Assumed			6.547	4.000	.003	5341.200	815.781	3076.228	7606.172
Cl	Assumed	5.197	.072	5.567	5	.003	446.000	80.108	240.075	651.925
	Not Assumed			9.316	4.000	.001	446.000	47.874	313.081	578.919
K	Assumed	5.633	.064	-2.162	5	.083	-.57200	.26454	-1.25203	.10803
	Not Assumed			-3.618	4.000	.022	-.57200	.15809	-1.01094	-.13306
Ca	Assumed	4.098	.099	-1.115	5	.315	-.65200	.58452	-2.15456	.85056
	Not Assumed			-1.866	4.000	.135	-.65200	.34932	-1.62187	.31787
Sc	Assumed	3.342	.127	-7.086	5	.001	-10.200	1.439	-13.900	-6.500
	Not Assumed			-11.857	4.000	.000	-10.200	.860	-12.588	-7.812
V	Assumed	1.853	.232	-3.629	5	.015	-36.200	9.976	-61.843	-10.557
	Not Assumed			-6.072	4.000	.004	-36.200	5.962	-52.752	-19.648
Cr	Assumed	2.073	.209	-7.520	5	.001	-94.200	12.526	-126.400	-62.000
	Not Assumed			-12.584	4.000	.000	-94.200	7.486	-114.984	-73.416
Mn	Assumed	2.537	.172	.461	5	.664	.144000	.312136	-.658371	.946371
	Not Assumed			.772	4.000	.483	.144000	.186537	-.373909	.661909
Fe	Assumed	22.287	.005	-1.476	5	.200	-1.870000	1.266970	-5.126849	1.386849
	Not Assumed			-2.470	4.000	.069	-1.870000	.757159	-3.972211	.232211
Ni	Assumed	1.916	.225	-6.550	5	.001	-44.60000	6.80941	-62.10413	-27.09587
	Not Assumed			-10.960	4.000	.000	-44.60000	4.06940	-55.89846	-33.30154
Cu	Assumed	3.767	.110	-3.675	5	.014	-10.40000	2.82984	-17.67434	-3.12566
	Not Assumed			-6.150	4.000	.004	-10.40000	1.69115	-15.09539	-5.70461
Zn	Assumed	2.081	.209	.981	5	.372	5.20000	5.30208	-8.42942	18.82942
	Not Assumed			1.641	4.000	.176	5.20000	3.16860	-3.59743	13.99743
Ga	Assumed	7.912	.037	-2.292	5	.070	-5.00000	2.18174	-10.60835	.60835
	Not Assumed			-3.835	4.000	.019	-5.00000	1.30384	-8.62004	-1.37996
Rb	Assumed	3.839	.107	-1.721	5	.146	-13.180000	7.659969	-32.870576	6.510576
	Not Assumed			-2.879	4.000	.045	-13.180000	4.577707	-25.889752	-.470248
Sr	Assumed	18.287	.008	-.961	5	.381	-63.220000	65.800753	-232.366221	105.926221
	Not Assumed			-1.608	4.000	.183	-63.220000	39.323471	-172.399460	45.959460
Y	Assumed	3.928	.104	-8.867	5	.000	-12.060000	1.360029	-15.556067	-8.563933
	Not Assumed			-14.838	4.000	.000	-12.060000	.812773	-14.316620	-9.803380
Zr	Assumed	7.460	.041	-5.060	5	.004	-132.780000	26.243634	-200.241409	-65.318591
	Not Assumed			-8.466	4.000	.001	-132.780000	15.683571	-176.324574	-89.235426
Ba	Assumed	6.124	.056	3.844	5	.012	210.000000	54.633323	69.560572	350.439428
	Not Assumed			6.432	4.000	.003	210.000000	32.649655	119.350024	300.649976
Ce	Assumed	3.673	.113	-11.832	5	.000	-14.000000	1.183216	-17.041553	-10.958447
	Not Assumed			-19.799	4.000	.000	-14.000000	.707107	-15.963243	-12.036757
Pb	Assumed	3.267	.131	.654	5	.542	2.485600	3.802729	-7.289626	12.260826
	Not Assumed			1.094	4.000	.336	2.485600	2.272565	-3.824053	8.795253
Li	Assumed	2.218	.197	.868	5	.425	2.668800	3.073362	-5.231529	10.569129
	Not Assumed			1.453	4.000	.220	2.668800	1.836685	-2.430656	7.768256
Nb	Assumed	1.937	.223	-5.650	5	.002	-6.580000	1.164612	-9.573729	-3.586271

	Not Assumed			-9.454	4.000	.001	-6.580000	.695989	-8.512374	-4.647626
Mo	Assumed	4.018	.101	-5.964	5	.002	-1.209800	.202847	-1.731235	-.688365
	Not Assumed			-9.980	4.000	.001	-1.209800	.121224	-1.546373	-.873227
Cs	Assumed	6.196	.055	-.437	5	.680	-.031000	.070908	-.213275	.151275
	Not Assumed			-.732	4.000	.505	-.031000	.042376	-.148654	.086654
La	Assumed	3.472	.121	-1.163	5	.297	-6.626000	5.698868	-21.275407	8.023407
	Not Assumed			-1.946	4.000	.124	-6.626000	3.405725	-16.081809	2.829809
Pr	Assumed	7.245	.043	-.995	5	.365	-1.227200	1.233135	-4.397076	1.942676
	Not Assumed			-1.665	4.000	.171	-1.227200	.736939	-3.273272	.818872
Nd	Assumed	8.879	.031	-.749	5	.488	-3.254800	4.348430	-14.432795	7.923195
	Not Assumed			-1.252	4.000	.279	-3.254800	2.598684	-10.469903	3.960303
Sm	Assumed	4.979	.076	-.018	5	.987	-.014400	.813669	-2.106003	2.077203
	Not Assumed			-.030	4.000	.978	-.014400	.486260	-1.364475	1.335675
Eu	Assumed	3.986	.102	.243	5	.818	.053200	.219053	-.509894	.616294
	Not Assumed			.406	4.000	.705	.053200	.130909	-.310262	.416662
Gd	Assumed	3.015	.143	.611	5	.568	.394800	.645755	-1.265166	2.054766
	Not Assumed			1.023	4.000	.364	.394800	.385912	-.676665	1.466265
Tb	Assumed	1.995	.217	.629	5	.557	.073600	.116961	-.227058	.374258
	Not Assumed			1.053	4.000	.352	.073600	.069897	-.120467	.267667
Dy	Assumed	1.992	.217	.840	5	.439	.634600	.755317	-1.307004	2.576204
	Not Assumed			1.406	4.000	.232	.634600	.451388	-.618654	1.887854
Ho	Assumed	2.155	.202	.739	5	.493	.126000	.170469	-.312203	.564203
	Not Assumed			1.237	4.000	.284	.126000	.101874	-.156849	.408849
Er	Assumed	1.919	.225	.822	5	.448	.351800	.427966	-.748321	1.451921
	Not Assumed			1.376	4.000	.241	.351800	.255758	-.358299	1.061899
Yb	Assumed	2.188	.199	.702	5	.514	.298200	.425021	-.794352	1.390752
	Not Assumed			1.174	4.000	.306	.298200	.253999	-.407013	1.003413
Lu	Assumed	2.178	.200	.505	5	.635	.030000	.059432	-.122776	.182776
	Not Assumed			.845	4.000	.446	.030000	.035518	-.068613	.128613
Hf	Assumed	3.511	.120	.488	5	.646	.207200	.424579	-.884215	1.298615
	Not Assumed			.817	4.000	.460	.207200	.253734	-.497280	.911680
Ta	Assumed	2.518	.173	.507	5	.634	.690600	1.361862	-2.810178	4.191378
	Not Assumed			.849	4.000	.444	.690600	.813868	-1.569061	2.950261
Tm	Assumed	2.163	.201	.858	5	.430	.057000	.066414	-.113723	.227723
	Not Assumed			1.436	4.000	.224	.057000	.039690	-.053197	.167197
Ti	Assumed	7.271	.043	-.089	5	.933	-.002400	.027016	-.071846	.067046
	Not Assumed			-.149	4.000	.889	-.002400	.016145	-.047226	.042426
Th	Assumed	8.751	.032	.520	5	.625	.715000	1.374135	-2.817326	4.247326
	Not Assumed			.871	4.000	.433	.715000	.821203	-1.565024	2.995024

Table B.14: Comparison of Control and On Site Elemental Means for Komaktorvik

Element	Control[1]	On Site[2]	Element	Control	On Site
Li	16.729	16.049	Mo	1.772	0.68000
Na[a]	2.44	2.1156	Pb	6.728	9.61800
K[a]	1.23	1.2669	Ga	15.54	14.3594
Rb	20.593	22.99125	Hf	1.183	0.86762
Cs	0.111	0.16375	Sc	0.0	13.50
Mg[a]	4.27	2.9319	Y	16.577	12.197
Ca[a]	4.83	4.1056	La	17.113	16.41237
Sr	259.43	278.402	Ce	33.312	30.490
Ba	440.02	487.30250	Pr	4.007	3.56894
P[a]	0.11	0.4475	Nd	14.787	13.04825
S	469	1428.31	Sm	2.952	2.43631
Cl	202	294.00	Eu	0.849	0.78819
Al[a]	12.7	11.6912	Gd	3.113	2.32112
Ti	0.043	0.13881	Tb	0.496	0.36281
V	108.0	80.06	Dy	3.343	2.35981
Cr	242.0	161.50	Ho	0.673	0.47462
Mn[a]	0.1	0.07062	Er	1.909	1.39206
Fe[a]	6.88	5.19938	Tm	0.261	0.22638
Ni	56.83	38.3200	Yb	1.81	1.29988
Cu	7.16	7.6462	Lu	0.263	0.18169
Zn	7.01	1.5125	Ta	1.172	1.77538
Zr	82.48	76.046	Th	1.629	1.68125
Nb	3.82	3.4135			

a= reported in % weight of their oxide; remaining elements reported in ppm
1= (n=1) 2=(n=16)

Table B.15: Independent-Samples T-Test for 45 Elements At Komaktorvik

	Equal Variances	Levene's Test		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Na	Assumed	2.513	.133	-1.277	16	.220	-.32437	.25405	-.86293	.21418
	Not Assumed			-3.709	15.000	.002	-.32437	.08746	-.51079	-.13796
Mg	Assumed	6.990	.018	-2.798	16	.013	-1.33813	.47826	-2.35200	-.32425
	Not Assumed			-8.127	15.000	.000	-1.33813	.16465	-1.68907	-.98718
Al	Assumed	2.535	.131	-1.124	16	.277	-1.00875	.89726	-2.91085	.89335
	Not Assumed			-3.266	15.000	.005	-1.00875	.30889	-1.66714	-.35036
P	Assumed	4.149	.059	2.049	16	.057	.33750	.16471	-.01167	.68667
	Not Assumed			5.952	15.000	.000	.33750	.05670	.21664	.45836
S	Assumed	2.246	.153	1.500	16	.153	959.312	639.660	-396.707	2315.332
	Not Assumed			4.356	15.000	.001	959.312	220.213	489.940	1428.685
Cl	Assumed	4.268	.055	1.736	16	.102	92.000	53.000	-20.355	204.355

	Not Assumed			5.042	15.000	.000	92.000	18.246	53.110	130.890
K	Assumed	2.116	.165	.502	16	.623	.03687	.07352	-.11898	.19273
	Not Assumed			1.457	15.000	.166	.03687	.02531	-.01707	.09082
Ca	Assumed	3.598	.076	-4.348	16	.000	-.72438	.16659	-1.07753	-.37122
	Not Assumed			-12.631	15.000	.000	-.72438	.05735	-.84662	-.60213
Sc	Assumed	1.411	.252	4.076	16	.001	13.500	3.312	6.479	20.521
	Not Assumed			11.840	15.000	.000	13.500	1.140	11.070	15.930
V	Assumed	7.072	.017	-3.779	16	.002	-27.938	7.394	-43.611	-12.264
	Not Assumed			-10.976	15.000	.000	-27.938	2.545	-33.363	-22.512
Cr	Assumed	11.664	.004	-4.030	16	.001	-80.500	19.977	-122.850	-38.150
	Not Assumed			-11.705	15.000	.000	-80.500	6.877	-95.159	-65.841
Mn	Assumed	9.168	.008	-3.019	16	.008	-.029375	.009732	-.050005	-.008745
	Not Assumed			-8.768	15.000	.000	-.029375	.003350	-.036516	-.022234
Fe	Assumed	5.243	.036	-3.224	16	.005	-1.680625	.521280	-2.785690	-.575560
	Not Assumed			-9.365	15.000	.000	-1.680625	.179459	-2.063132	-1.298118
Ni	Assumed	8.268	.011	-3.257	16	.005	-18.51000	5.68258	-30.55653	-6.46347
	Not Assumed			-9.462	15.000	.000	-18.51000	1.95631	-22.67978	-14.34022
Cu	Assumed	4.196	.057	.356	16	.727	.48625	1.36609	-2.40973	3.38223
	Not Assumed			1.034	15.000	.318	.48625	.47030	-.51617	1.48867
Zn	Assumed	2.418	.140	-2.264	16	.038	-5.49750	2.42823	-10.64512	-.34988
	Not Assumed			-6.576	15.000	.000	-5.49750	.83595	-7.27930	-3.71570
Ga	Assumed	4.134	.059	-1.407	16	.179	-1.18062	.83909	-2.95941	.59816
	Not Assumed			-4.087	15.000	.001	-1.18062	.28887	-1.79634	-.56491
Rb	Assumed	1.344	.263	1.547	16	.141	2.398250	1.550558	-.888785	5.685285
	Not Assumed			4.493	15.000	.000	2.398250	.533803	1.260476	3.536024
Sr	Assumed	3.591	.076	1.310	16	.209	18.972500	14.479636	-11.722957	49.667957
	Not Assumed			3.806	15.000	.002	18.972500	4.984835	8.347577	29.597423
Y	Assumed	4.084	.060	-1.922	16	.073	-4.379250	2.278536	-9.209531	.451031
	Not Assumed			-5.583	15.000	.000	-4.379250	.784421	-6.051203	-2.707297
Zr	Assumed	2.702	.120	-1.110	16	.283	-6.433750	5.796362	-18.721488	5.853988
	Not Assumed			-3.224	15.000	.006	-6.433750	1.995486	-10.687027	-2.180473
Ba	Assumed	3.524	.079	1.432	16	.171	47.282500	33.024945	-22.727256	117.292256
	Not Assumed			4.159	15.000	.001	47.282500	11.369339	23.049328	71.515672
Ce	Assumed	3.059	.099	-1.757	16	.098	-2.821750	1.605787	-6.225867	.582367
	Not Assumed			-5.104	15.000	.000	-2.821750	.552817	-4.000051	-1.643449
Pb	Assumed	1.570	.228	1.032	16	.318	2.890000	2.801689	-3.049316	8.829316
	Not Assumed			2.996	15.000	.009	2.890000	.964524	.834166	4.945834
Li	Assumed	4.608	.048	-4.717	16	.000	-5.827000	1.235295	-8.445709	-3.208291
	Not Assumed			-13.702	15.000	.000	-5.827000	.425269	-6.733440	-4.920560
Nb	Assumed	8.371	.011	-1.746	16	.100	-.406437	.232827	-.900009	.087134
	Not Assumed			-5.071	15.000	.000	-.406437	.080154	-.577282	-.235593
Mo	Assumed	3.833	.068	-2.763	16	.014	-1.092000	.395290	-1.929978	-.254022
	Not Assumed			-8.024	15.000	.000	-1.092000	.136085	-1.382058	-.801942
Cs	Assumed	3.894	.066	1.743	16	.101	.052750	.030267	-.011412	.116912
	Not Assumed			5.063	15.000	.000	.052750	.010420	.030541	.074959
La	Assumed	3.058	.099	-1.011	16	.327	-.700625	.692675	-2.169030	.767780

	Not Assumed			-2.938	15.000	.010	-.700625	.238464	-1.208899	-.192351
Pr	Assumed	1.540	.233	-2.325	16	.034	-.438062	.188453	-.837565	-.038560
	Not Assumed			-6.752	15.000	.000	-.438062	.064878	-.576346	-.299779
Nd	Assumed	1.718	.208	-2.817	16	.012	-1.738750	.617344	-3.047461	-.430039
	Not Assumed			-8.181	15.000	.000	-1.738750	.212530	-2.191747	-1.285753
Sm	Assumed	3.011	.102	-3.046	16	.008	-.515687	.169316	-.874622	-.156753
	Not Assumed			-8.847	15.000	.000	-.515687	.058290	-.639929	-.391446
Eu	Assumed	3.959	.064	-1.843	16	.084	-.060813	.032989	-.130745	.009120
	Not Assumed			-5.355	15.000	.000	-.060813	.011357	-.085019	-.036606
Gd	Assumed	5.107	.038	-2.427	16	.027	-.791875	.326243	-1.483479	-.100271
	Not Assumed			-7.051	15.000	.000	-.791875	.112314	-1.031267	-.552483
Tb	Assumed	4.243	.056	-2.283	16	.036	-.133187	.058330	-.256842	-.009533
	Not Assumed			-6.632	15.000	.000	-.133187	.020081	-.175989	-.090386
Dy	Assumed	4.968	.040	-2.310	16	.035	-.983188	.425642	-1.885509	-.080866
	Not Assumed			-6.710	15.000	.000	-.983188	.146534	-1.295517	-.670858
Ho	Assumed	4.285	.055	-2.157	16	.047	-.198375	.091957	-.393316	-.003434
	Not Assumed			-6.266	15.000	.000	-.198375	.031658	-.265852	-.130898
Er	Assumed	5.149	.037	-2.033	16	.059	-.516938	.254288	-1.056003	.022128
	Not Assumed			-5.905	15.000	.000	-.516938	.087542	-.703530	-.330345
Yb	Assumed	5.989	.026	-2.011	16	.061	-.510125	.253664	-1.047869	.027619
	Not Assumed			-5.842	15.000	.000	-.510125	.087328	-.696260	-.323990
Lu	Assumed	4.617	.047	-2.152	16	.047	-.081313	.037789	-.161422	-.001203
	Not Assumed			-6.250	15.000	.000	-.081313	.013010	-.109042	-.053583
Hf	Assumed	2.442	.138	-2.027	16	.060	-.315375	.155568	-.645164	.014414
	Not Assumed			-5.889	15.000	.000	-.315375	.053557	-.429528	-.201222
Ta	Assumed	4.663	.046	1.259	16	.226	.603375	.479181	-.412443	1.619193
	Not Assumed			3.658	15.000	.002	.603375	.164965	.251760	.954990
Tm	Assumed	4.106	.060	-.931	16	.366	-.034625	.037189	-.113463	.044213
	Not Assumed			-2.704	15.000	.016	-.034625	.012803	-.061914	-.007336
Ti	Assumed	4.313	.054	3.718	16	.002	.095813	.025770	.041182	.150443
	Not Assumed			10.800	15.000	.000	.095813	.008872	.076903	.114722
Th	Assumed	1.658	.216	.169	16	.868	.052250	.308586	-.601924	.706424
	Not Assumed			.492	15.000	.630	.052250	.106236	-.174186	.278686

Table B.16: Comparison of Control and On Site Elemental Means for Big Head

Element	Control[1]	On Site[2]	Element	Control	On Site
Li	11.424	6.33550	Mo	0.155	0.06400
Na[a]	1.80	1.3550	Pb	3.802	5.12400
K[a]	0.76	0.7250	Ga	17.15	9.4550
Rb	6.502	11.14550	Hf	0.742	0.22250
Cs	0.019	0.15450	Sc	30.0	22.00
Mg[a]	4.62	2.0100	Y	18.771	11.24600
Ca[a]	7.41	4.5700	La	8.506	13.43700
Sr	168.17	236.11500	Ce	18.519	24.79650
Ba	123.38	247.68	Pr	2.426	3.00050
P[a]	0.29	1.1550	Nd	10.018	10.70350
S	3126	6546	Sm	2.306	1.74300
Cl	583	1059.50	Eu	0.681	0.51200
Al[a]	10.87	7.6850	Gd	3.0	1.64050
Ti	0.0	0.00450	Tb	0.501	0.26450
V	230	93.50	Dy	3.558	1.914500
Cr	222	230.00	Ho	0.725	0.36750
Mn[a]	0.17	0.08500	Er	2.087	1.040000
Fe[a]	12.04	7.01500	Tm	0.283	0.16150
Ni	53.59	57.6050	Yb	1.921	0.82450
Cu	19.38	21.2650	Lu	0.275	0.10550
Zn	0.0	14.0150	Ta	1.73	0.85750
Zr	76.34	68.49500	Th	1.57	1.50150
Nb	3.653	2.57350			

a= reported in % weight of their oxide; remaining elements reported in ppm
1= (n=1) 2=(n=2)

Table B.17: Independent-Samples T-Test for 45 Elements At Big Head

	Equal Variances	Levene's Test		t-test for Equality of Means						
									95% Confidence Interval of Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Na	Assumed	1.474E16	.000	-5.933	2	.027	-.44500	.07500	-.76770	-.12230
	Not Assumed			-5.933	1.000	.106	-.44500	.07500	-1.39797	.50797
Mg	Assumed	2.144E16	.000	-21.750	2	.002	-2.61000	.12000	-3.12632	-2.09368
	Not Assumed			-21.750	1.000	.029	-2.61000	.12000	-4.13474	-1.08526
Al	Assumed	.	.	-20.548	2	.002	-3.18500	.15500	-3.85191	-2.51809
	Not Assumed			-20.548	1.000	.031	-3.18500	.15500	-5.15446	-1.21554
P	Assumed	1.445E17	.000	2.836	2	.105	.86500	.30500	-.44731	2.17731
	Not Assumed			2.836	1.000	.016	.86500	.30500	-3.01039	4.74039
S	Assumed	.	.	30.811	2	.001	3420.000	111.000	2942.406	3897.594

	Not Assumed			30.811	1.000	.021	3420.000	111.000	2009.611	4830.389
Cl	Assumed	.	.	12.562	2	.006	201.000	16.000	132.158	269.842
	Not Assumed			12.562	1.000	.051	201.000	16.000	-2.299	404.299
K	Assumed	.	.	-1.000	2	.423	-.03500	.03500	-.18559	.11559
	Not Assumed			-1.000	1.000	.500	-.03500	.03500	-.47972	.40972
Ca	Assumed	.	.	-5.680	2	.030	-2.84000	.50000	-4.99133	-.68867
	Not Assumed			-5.680	1.000	.111	-2.84000	.50000	-9.19310	3.51310
Sc	Assumed	.	.	-2.000	2	.184	-8.000	4.000	-25.211	9.211
	Not Assumed			-2.000	1.000	.295	-8.000	4.000	-58.825	42.825
V	Assumed	.	.	-39.000	2	.001	-136.500	3.500	-151.559	-121.441
	Not Assumed			-39.000	1.000	.016	-136.500	3.500	-180.972	-92.028
Cr	Assumed	.	.	.533	2	.647	8.000	15.000	-56.540	72.540
	Not Assumed			.533	1.000	.688	8.000	15.000	-182.593	198.593
Mn	Assumed	.	.	-17.000	2	.003	-.085000	.005000	-.106513	-.063487
	Not Assumed			-17.000	1.000	.037	-.085000	.005000	-.148531	-.021469
Fe	Assumed	1.098E16	.000	-13.767	2	.005	-5.025000	.365000	-6.595468	-3.454532
	Not Assumed			-13.767	1.000	.046	-5.025000	.365000	-9.662765	-.387235
Ni	Assumed	.	.	.973	2	.433	4.01500	4.12500	-13.73344	21.76344
	Not Assumed			.973	1.000	.509	4.01500	4.12500	-48.39809	56.42809
Cu	Assumed	1.315E16	.000	1.839	2	.207	1.88500	1.02500	-2.52522	6.29522
	Not Assumed			1.839	1.000	.317	1.88500	1.02500	-11.13886	14.90886
Zn	Assumed	5.661E17	.000	1.000	2	.423	14.01500	14.01500	-46.28668	74.31668
	Not Assumed			1.000	1.000	.500	14.01500	14.01500	-164.06246	192.09246
Ga	Assumed	3.161E16	.000	-6.605	2	.022	-7.69500	1.16500	-12.70759	-2.68241
	Not Assumed			-6.605	1.000	.096	-7.69500	1.16500	-22.49773	7.10773
Rb	Assumed	.	.	2.822	2	.106	4.643500	1.645500	-2.436515	11.723515
	Not Assumed			2.822	1.000	.217	4.643500	1.645500	-16.264560	25.551560
Sr	Assumed	.	.	3.842	2	.062	67.945000	17.685000	-8.147414	144.037414
	Not Assumed			3.842	1.000	.162	67.945000	17.685000	-156.764231	292.654231
Y	Assumed	1.250E16	.000	-9.211	2	.012	-7.525000	.817000	-11.040267	-4.009733
	Not Assumed			-9.211	1.000	.069	-7.525000	.817000	-17.905969	2.855969
Zr	Assumed	.	.	-3.558	2	.071	-7.845000	2.205000	-17.332349	1.642349
	Not Assumed			-3.558	1.000	.174	-7.845000	2.205000	-35.862181	20.172181
Ba	Assumed	2.714E16	.000	5.533	2	.031	124.305000	22.465000	27.645906	220.964094
	Not Assumed			5.533	1.000	.114	124.305000	22.465000	-161.139889	409.749889
Ce	Assumed	.	.	4.933	2	.039	6.277500	1.272500	.802374	11.752626
	Not Assumed			4.933	1.000	.127	6.277500	1.272500	-9.891146	22.446146
Pb	Assumed	.	.	11.496	2	.007	1.322000	.115000	.827195	1.816805
	Not Assumed			11.496	1.000	.055	1.322000	.115000	-.139214	2.783214
Li	Assumed	.	.	-9.095	2	.012	-5.088500	.559500	-7.495834	-2.681166
	Not Assumed			-9.095	1.000	.070	-5.088500	.559500	-12.197622	2.020622
Nb	Assumed	.	.	-16.736	2	.004	-1.079500	.064500	-1.357021	-.801979

	Not Assumed			-16.736	1.000	.038	-1.079500	.064500	-1.899050	-.259950
Mo	Assumed	.	.	-1.422	2	.291	-.091000	.064000	-.366370	.184370
	Not Assumed			-1.422	1.000	.390	-.091000	.064000	-.904197	.722197
Cs	Assumed	2.992E16	.000	54.200	2	.000	.135500	.002500	.124743	.146257
	Not Assumed			54.200	1.000	.012	.135500	.002500	.103734	.167266
La	Assumed	.	.	6.783	2	.021	4.931000	.727000	1.802971	8.059029
	Not Assumed			6.783	1.000	.093	4.931000	.727000	-4.306411	14.168411
Pr	Assumed	.	.	4.889	2	.039	.574500	.117500	.068938	1.080062
	Not Assumed			4.889	1.000	.128	.574500	.117500	-.918479	2.067479
Nd	Assumed	.	.	1.098	2	.387	.685500	.624500	-2.001507	3.372507
	Not Assumed			1.098	1.000	.470	.685500	.624500	-7.249525	8.620525
Sm	Assumed	4.798E16	.000	-10.426	2	.009	-.563000	.054000	-.795343	-.330657
	Not Assumed			-10.426	1.000	.061	-.563000	.054000	-1.249135	.123135
Eu	Assumed	2.139E16	.000	-3.449	2	.075	-.169000	.049000	-.379830	.041830
	Not Assumed			-3.449	1.000	.180	-.169000	.049000	-.791604	.453604
Gd	Assumed	.	.	-9.344	2	.011	-1.359500	.145500	-1.985536	-.733464
	Not Assumed			-9.344	1.000	.068	-1.359500	.145500	-3.208253	.489253
Tb	Assumed	.	.	-8.298	2	.014	-.236500	.028500	-.359126	-.113874
	Not Assumed			-8.298	1.000	.076	-.236500	.028500	-.598627	.125627
Dy	Assumed	.	.	-8.860	2	.013	-1.643500	.185500	-2.441642	-.845358
	Not Assumed			-8.860	1.000	.072	-1.643500	.185500	-4.000501	.713501
Ho	Assumed	.	.	-8.412	2	.014	-.357500	.042500	-.540363	-.174637
	Not Assumed			-8.412	1.000	.075	-.357500	.042500	-.897514	.182514
Er	Assumed	1.700E16	.000	-9.348	2	.011	-1.047000	.112000	-1.528897	-.565103
	Not Assumed			-9.348	1.000	.068	-1.047000	.112000	-2.470095	.376095
Yb	Assumed	2.032E16	.000	-11.363	2	.008	-1.096500	.096500	-1.511706	-.681294
	Not Assumed			-11.363	1.000	.056	-1.096500	.096500	-2.322649	.129649
Lu	Assumed	5.033E16	.000	-7.533	2	.017	-.169500	.022500	-.266310	-.072690
	Not Assumed			-7.533	1.000	.084	-.169500	.022500	-.455390	.116390
Hf	Assumed	3.441E17	.000	-10.287	2	.009	-.519500	.050500	-.736784	-.302216
	Not Assumed			-10.287	1.000	.062	-.519500	.050500	-1.161163	.122163
Ta	Assumed	1.466E16	.000	-3.067	2	.092	-.872500	.284500	-2.096605	.351605
	Not Assumed			-3.067	1.000	.201	-.872500	.284500	-4.487415	2.742415
Tm	Assumed	5.042E16	.000	-7.364	2	.018	-.121500	.016500	-.192494	-.050506
	Not Assumed			-7.364	1.000	.086	-.121500	.016500	-.331152	.088152
Ti	Assumed	.	.	9.000	2	.012	.004500	.000500	.002349	.006651
	Not Assumed			9.000	1.000	.070	.004500	.000500	-.001853	.010853
Th	Assumed	2.651E16	.000	-2.322	2	.146	-.068500	.029500	-.195428	.058428
	Not Assumed			-2.322	1.000	.259	-.068500	.029500	-.443333	.306333

Table B.18: Correlation Matrix for pH, Eh, and TDS

		LOGpH	LOGEh	LOGTDS
Correlation	LOGpH	1.000	-0.638	-0.352
	LOGEh	-.0638	1.000	0.444
	LOGTDS	-0.352	0.444	1.000
Sig. (1-tailed)	LOGpH		0.000	0.015
	LOGEh	0.000		0.003
	LOGTDS	0.015	0.003	

Determinant =0.471
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.627
Bartlett's Test of Sphericity p=0.000

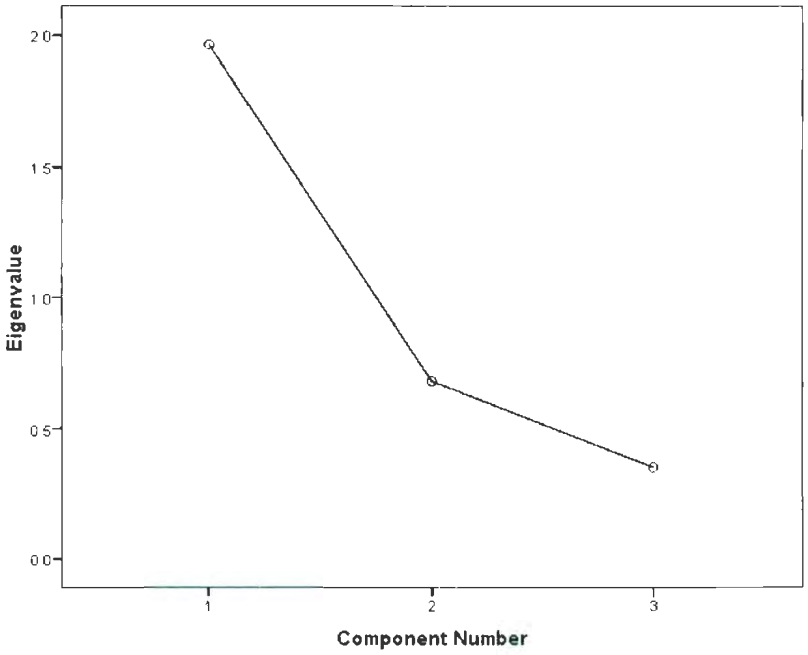

Figure B.10: Screeplot for pH, Eh, and TDS

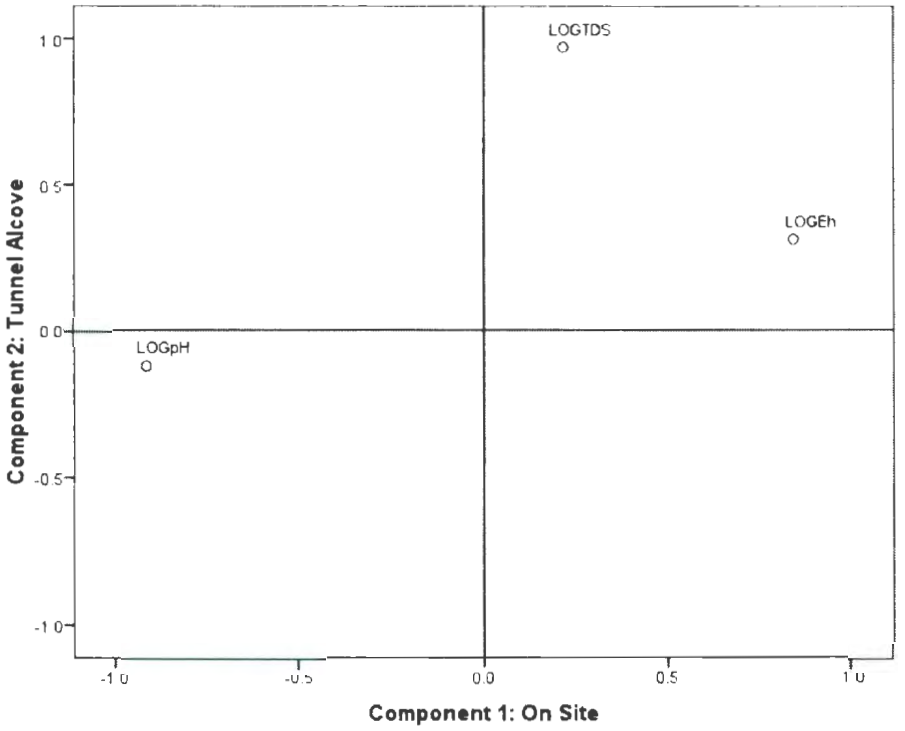

Figure B.11: Rotated Component Loading Plot for pH, Eh, and TDS

Table B.19: Correlation Matrix for Li, Na, K, Rb, and Cs

		LOGLi	LOGNa	LOGK	LOGRb	LOGCs
Correlation	LOGLi	1.000	0.288	0.060	-0.032	-0.006
	LOGNa	0.288	1.000	0.790	0.717	0.438
	LOGK	0.060	0.790	1.000	0.972	0.846
	LOGRb	-0.032	0.717	0.972	1.000	0.848
	LOGCs	-0.006	0.438	0.846	0.848	1.000
Sig. (1-tailed)	LOGLi		0.040	0.361	0.424	0.486
	LOGNa	0.040		0.000	0.000	0.003
	LOGK	0.361	0.000		0.000	0.000
	LOGRb	0.424	0.000	0.000		0.000
	LOGCs	0.486	0.003	0.000	0.000	

Determinant = 0.002
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.632
Bartlett's Test of Sphericity p=0.000

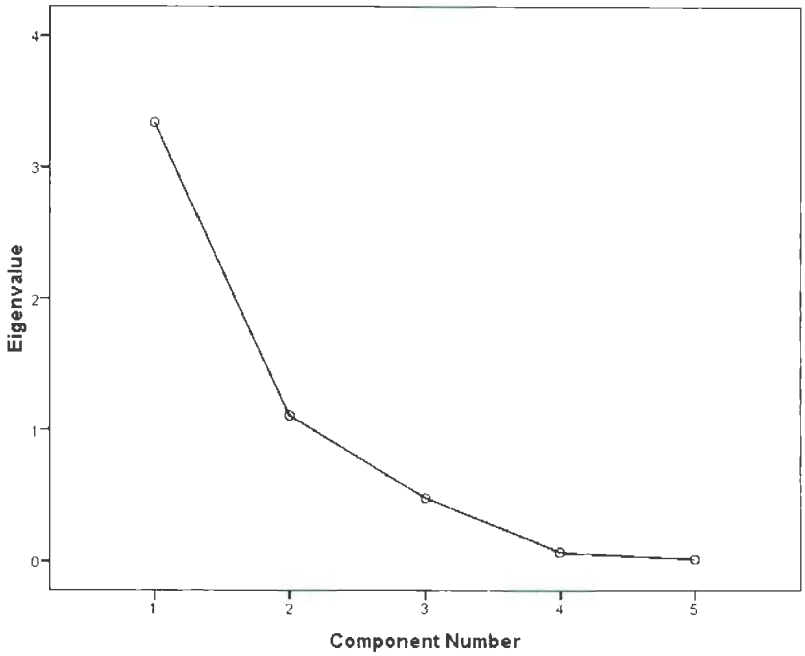

Figure B.12: Screeplot for Li, Na, K, Rb, and Cs

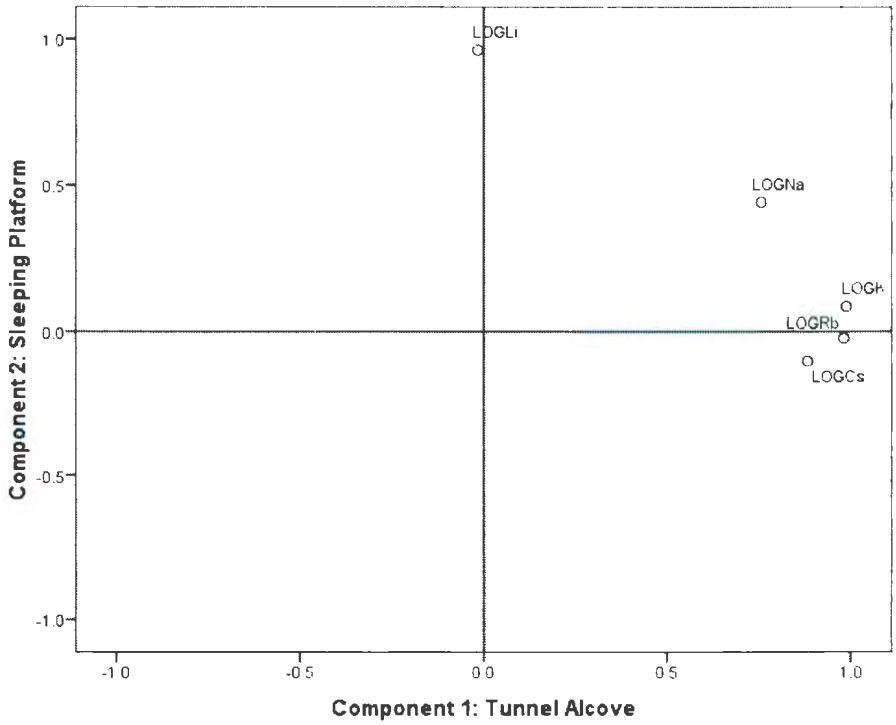

Figure B.13: Rotated Component Loading Plot for Li, Na, K, Rb, and Cs

Table B.20: Correlation Matrix for Mg, Ca, Sr, and Ba

		LOGMg	LOGCa	LOGSr	LOGBa
Correlation	LOGMg	1.000	0.847	-0.150	-0.792
	LOGCa	0.847	1.000	-0.249	-0.819
	LOGSr	-0.150	-0.249	1.000	0.560
	LOGBa	-0.792	-0.819	0.560	1.000
Sig. (1-tailed)	LOGMg		0.000	0.185	0.000
	LOGCa	0.000		0.066	0.000
	LOGSr	0.185	0.066		0.000
	LOGBa	0.000	0.000	0.000	

Determinant = 0.037
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.634
Bartlett's Test of Sphericity p=0.000

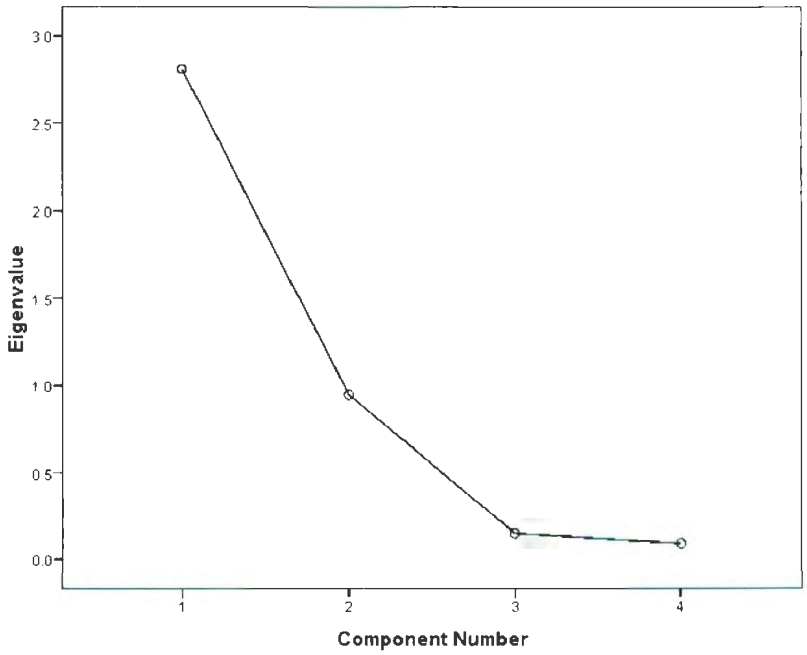

Figure B.14: Screeplot for Mg, Ca, Sr, and Ba

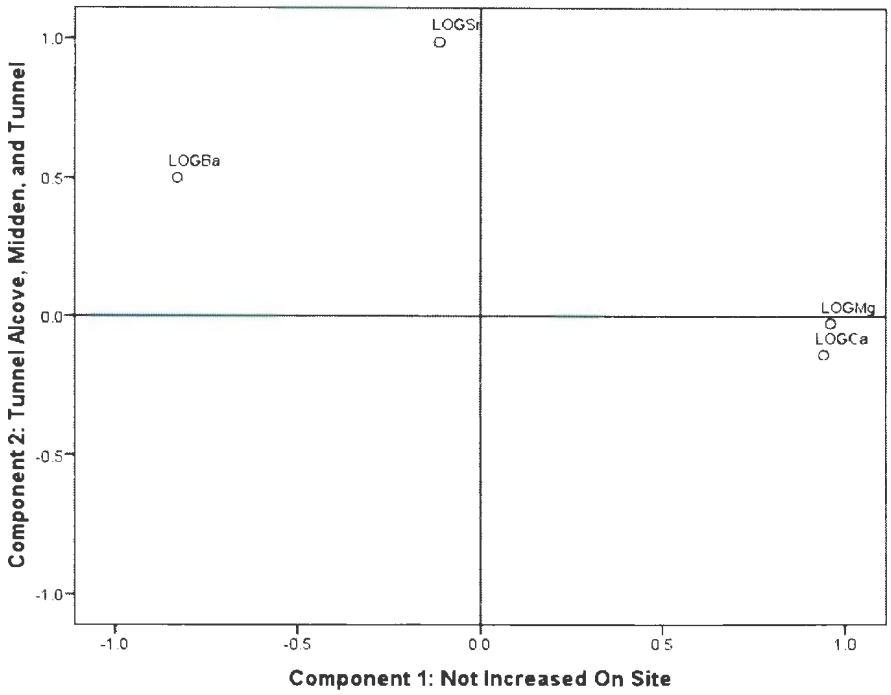

Figure B.15: Rotated Component Loading Plot for Mg, Ca, Sr, and Ba

Table B.21: Correlation Matrix for P, S, and Cl

		LOGP	LOGS	LOGCl
Correlation	LOGP	1.000	0.821	0.760
	LOGS	0.821	1.000	0.903
	LOGCl	0.760	0.903	1.000
Sig. (1-tailed)	LOGP		0.000	0.000
	LOGS	0.000		0.000
	LOGCl	0.000	0.000	

Determinant = 0.060
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.720
Bartlett's Test of Sphericity p=0.000

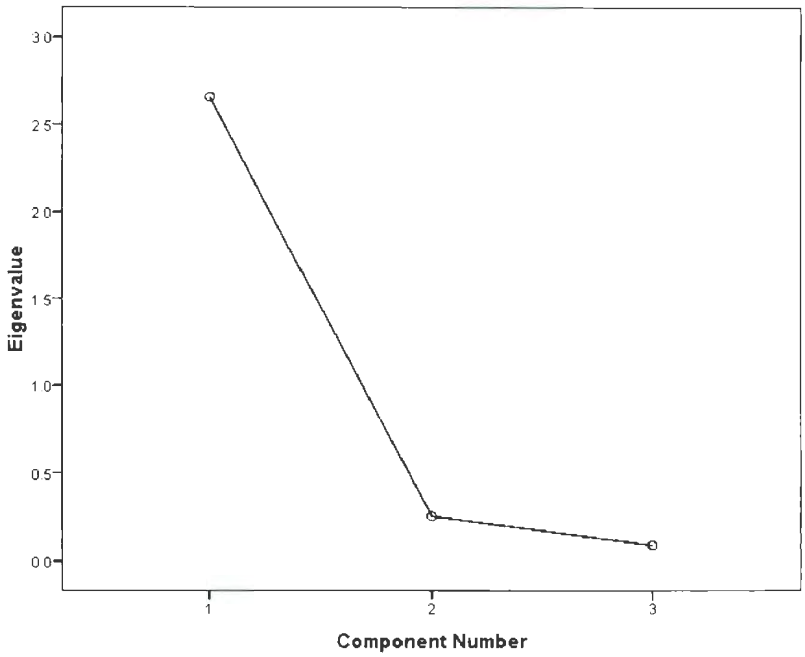

Figure B.16: Screeplot for P, S, and Cl

Table B.22: Correlation Matrix for Ti, V, Cr, Mn, Fe, Ni, and Cu

		LOGTi	LOGV	LOGCr	LOGMn	LOGFe	LOGNi	LOGCu
Correlation	LOGTi	1.000	-0.935	-0.935	-0.334	-0.940	-0.879	-0.847
	LOGV	-0.935	1.000	0.929	0.326	0.947	0.874	0.898
	LOGCr	-0.935	0.929	1.000	0.245	0.890	0.935	0.842
	LOGMn	-0.334	0.326	0.245	1.000	0.420	0.239	0.325
	LOGFe	-0.940	0.947	0.890	0.420	1.000	0.838	0.834
	LOGNi	-0.879	0.874	0.935	0.239	0.838	1.000	0.840
	LOGCu	-0.847	0.898	0.842	0.325	0.834	0.840	1.000
Sig. (1-tailed)	LOGTi		0.000	0.000	0.020	0.000	0.000	0.000
	LOGV	0.000		0.000	0.023	0.000	0.000	0.000
	LOGCr	0.000	0.000		0.069	0.000	0.000	0.000
	LOGMn	0.020	0.023	0.069		0.004	0.074	0.023
	LOGFe	0.000	0.000	0.000	0.004		0.000	0.000
	LOGNi	0.000	0.000	0.000	0.074	0.000		0.000
	LOGCu	0.000	0.000	0.000	0.023	0.000	0.000	

Determinant = 1.49E-005
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.862
Bartlett's Test of Sphericity p=0.000

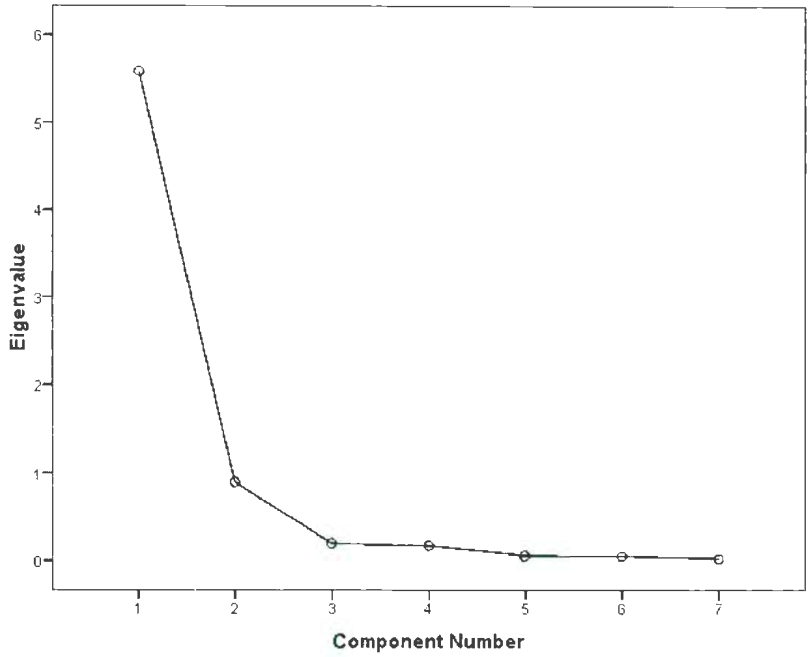

Figure B.17: Screeplot for Ti, V, Cr, Mn, Fe, Ni, and Cu

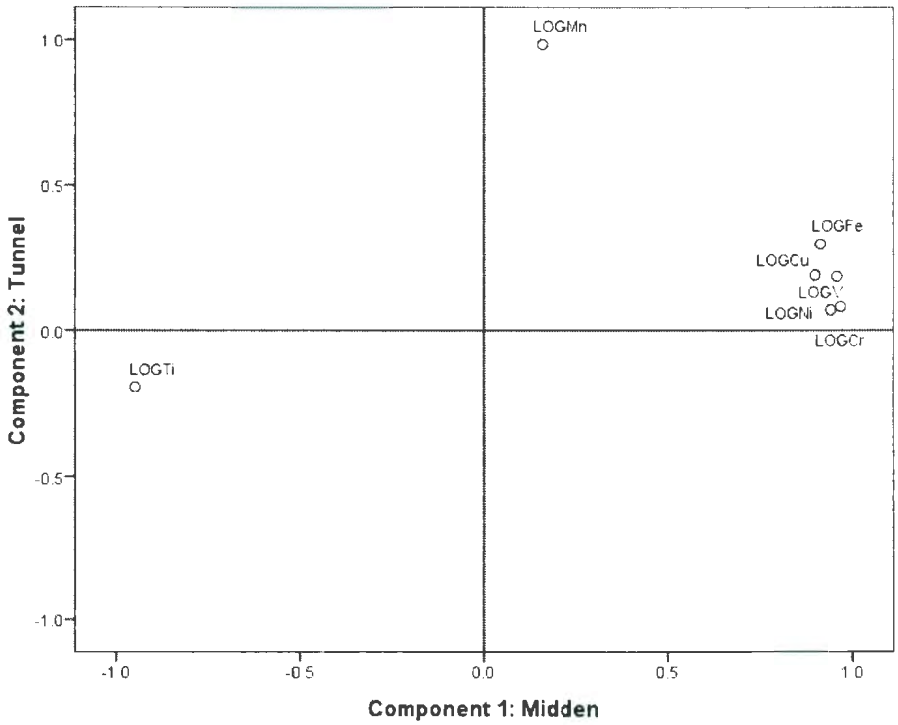

Figure B.18: Rotated Component Loading Plot for Ti, V, Cr, Mn, Fe, Ni, and Cu

Table B.23: Correlation Matrix for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

		LOGZn	LOGZr	LOGNb	LOGMo	LOGPb	LOGGa	LOGHf
Correlation	LOGZn	1.000	0.115	-0.100	-0.197	-0.340	-0.371	-0.332
	LOGZr	0.115	1.000	0.847	0.402	0.443	0.523	0.278
	LOGNb	-0.100	0.847	1.000	0.600	0.622	0.668	0.523
	LOGMo	-0.197	0.402	0.600	1.000	0.438	0.590	0.633
	LOGPb	-0.340	0.443	0.622	0.438	1.000	0.506	0.554
	LOGGa	-0.371	0.523	0.668	0.590	0.506	1.000	0.464
	LOGHf	-0.332	0.278	0.523	0.633	0.554	0.464	1.000
Sig. (1-tailed)	LOGZn		0.246	0.275	0.118	0.018	0.011	0.021
	LOGZr	0.246		0.000	0.006	0.003	0.000	0.046
	LOGNb	0.275	0.000		0.000	0.000	0.000	0.000
	LOGMo	0.118	0.006	0.000		0.003	0.000	0.000
	LOGPb	0.018	0.003	0.000	0.003		0.001	0.000
	LOGGa	0.011	0.000	0.000	0.000	0.001		0.002
	LOGHf	0.021	0.046	0.000	0.000	0.000	0.002	

Determinant = 0.015
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.768
Bartlett's Test of Sphericity p=0.000

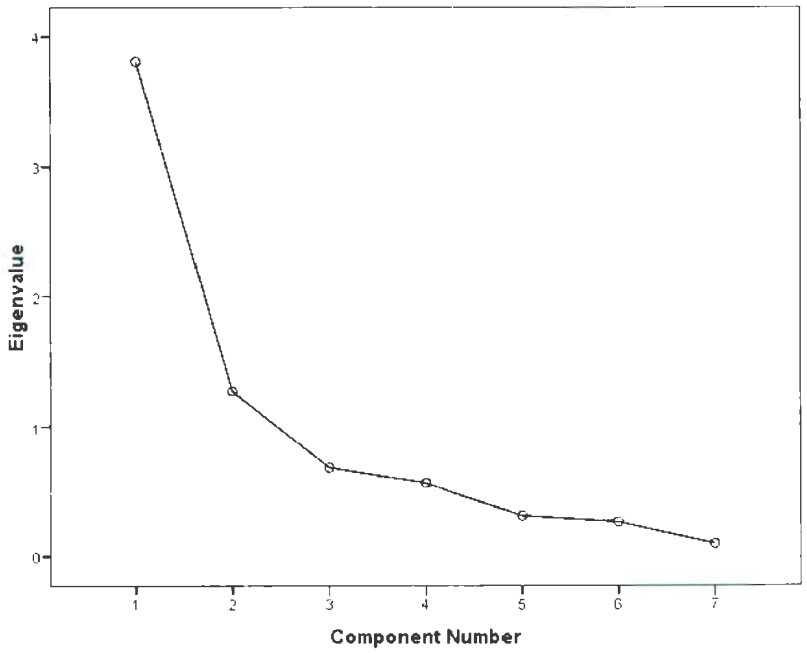

Figure B.19: Screeplot for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

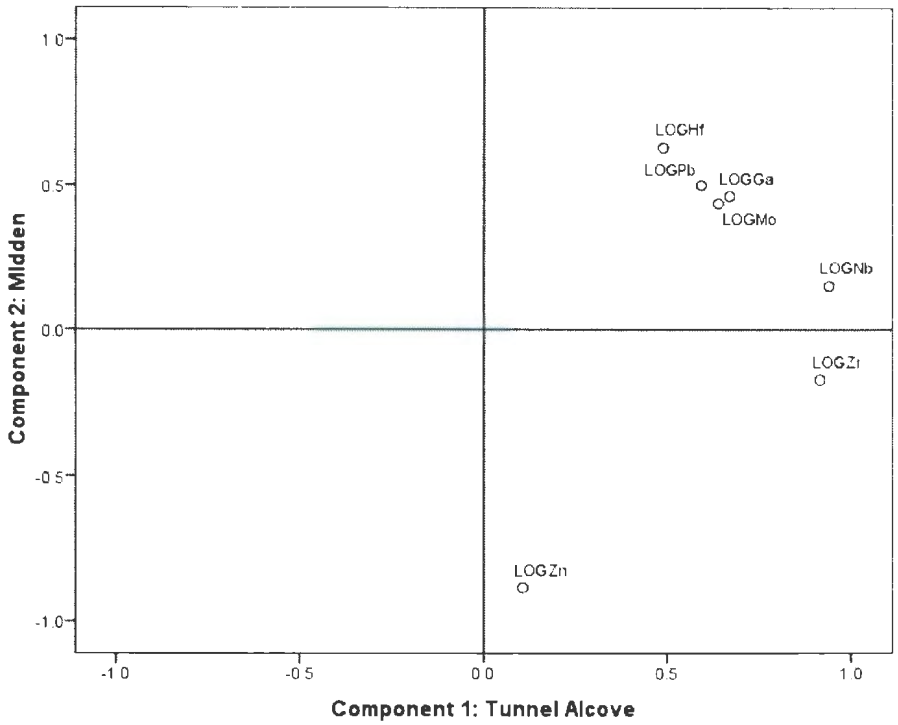

Figure B.20: Rotated Component Loading Plot for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

Table B.24: Correlation Matrix for Sc, Y, La, Ce, Pr, and Nd

		LOGSc	LOGY	LOGLa	LOGCe	LOGPr	LOGNd
Correlation	LOGSc	1.000	0.058	-0.246	-0.141	-0.258	-0.301
	LOGY	0.058	1.000	-0.323	-0.239	-0.239	-0.200
	LOGLa	-0.246	-0.323	1.000	0.898	0.978	0.952
	LOGCe	-0.141	-0.239	0.898	1.000	0.882	0.842
	LOGPr	-0.258	-0.239	0.978	0.882	1.000	0.990
	LOGNd	-0.301	-0.200	0.952	0.842	0.990	1.000
Sig. (1-tailed)	LOGSc		0.366	0.068	0.199	0.059	0.033
	LOGY	0.366		0.024	0.075	0.074	0.115
	LOGLa	0.068	0.024		0.000	0.000	0.000
	LOGCe	0.199	0.075	0.000		0.000	0.000
	LOGPr	0.059	0.074	0.000	0.000		0.000
	LOGNd	0.033	0.115	0.000	0.000	0.000	

Determinant = 5.70E-005
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.720
Bartlett's Test of Sphericity p=0.000

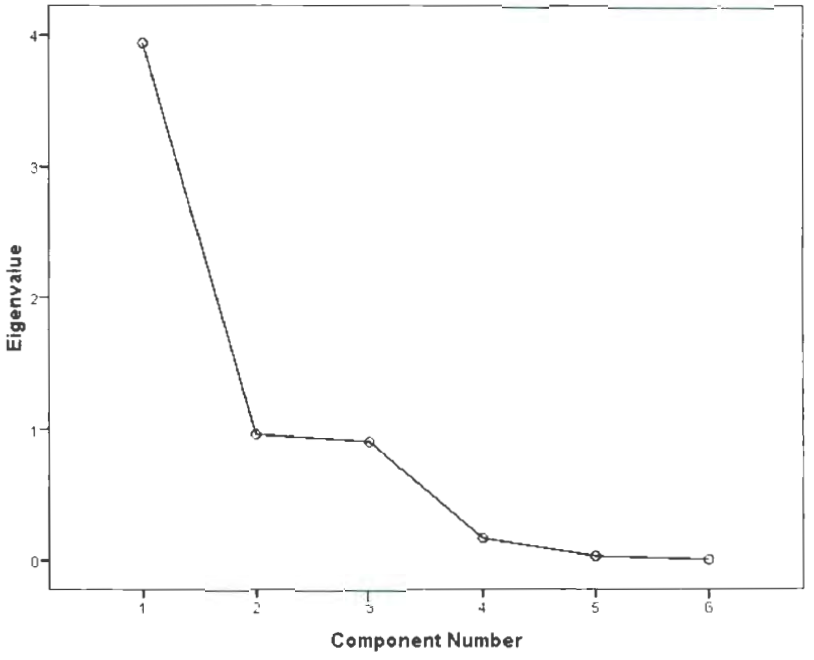

Figure B.21: Screeplot for Sc, Y, La, Ce, Pr, and Nd

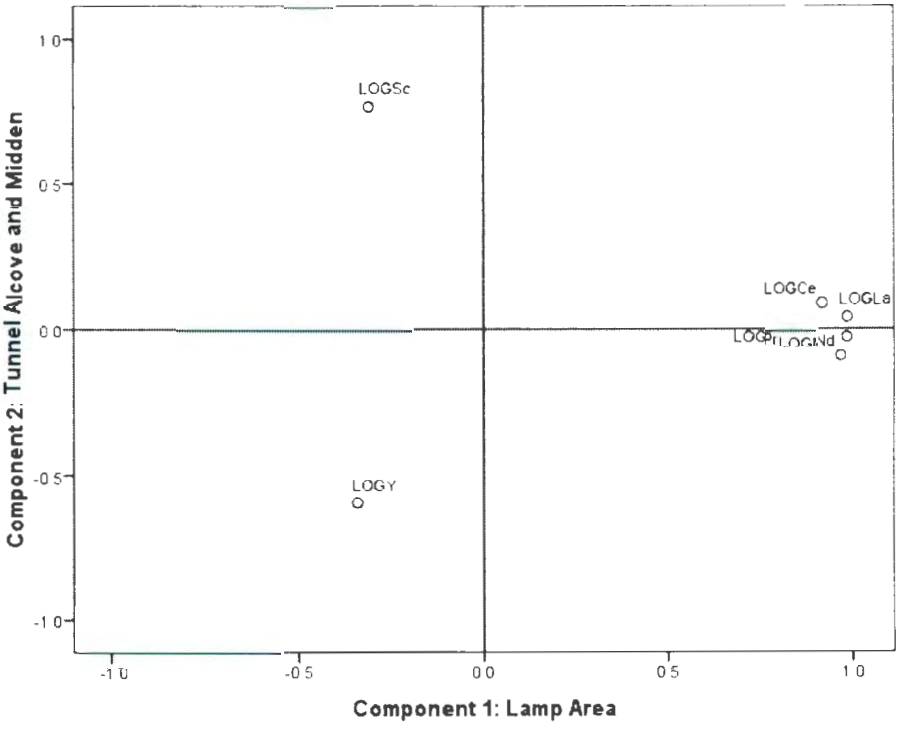

Figure B.22: Rotated Component Loading Plot for Sc, Y, La, Ce, Pr, and Nd

Table B.25: Correlation Matrix for Sm, Eu, Gd, Tb, Ho, and Er

		LOGSm	LOGEu	LOGGd	LOGTb	LOGHo	LOGEr
Correlation	LOGSm	1.000	0.599	0.642	0.527	0.467	0.433
	LOGEu	0.599	1.000	0.274	0.185	0.117	0.126
	LOGGd	0.642	0.274	1.000	0.945	0.916	0.918
	LOGTb	0.527	0.185	0.945	1.000	0.985	0.987
	LOGHo	0.467	0.117	0.916	0.985	1.000	0.984
	LOGEr	0.433	0.126	0.918	0.987	0.984	1.000
Sig. (1-tailed)	LOGSm		0.000	0.000	0.000	0.002	0.003
	LOGEu	0.000		0.048	0.133	0.242	0.226
	LOGGd	0.000	0.048		0.000	0.000	0.000
	LOGTb	0.000	0.133	0.000		0.000	0.000
	LOGHo	0.002	0.242	0.000	0.000		0.000
	LOGEr	0.003	0.226	0.000	0.000	0.000	

Determinant = 1.15E-005
Kaiser-Meyer-Olkin Measure of Sampling Adequacy=0.802
Bartlett's Test of Sphericity p=0.000

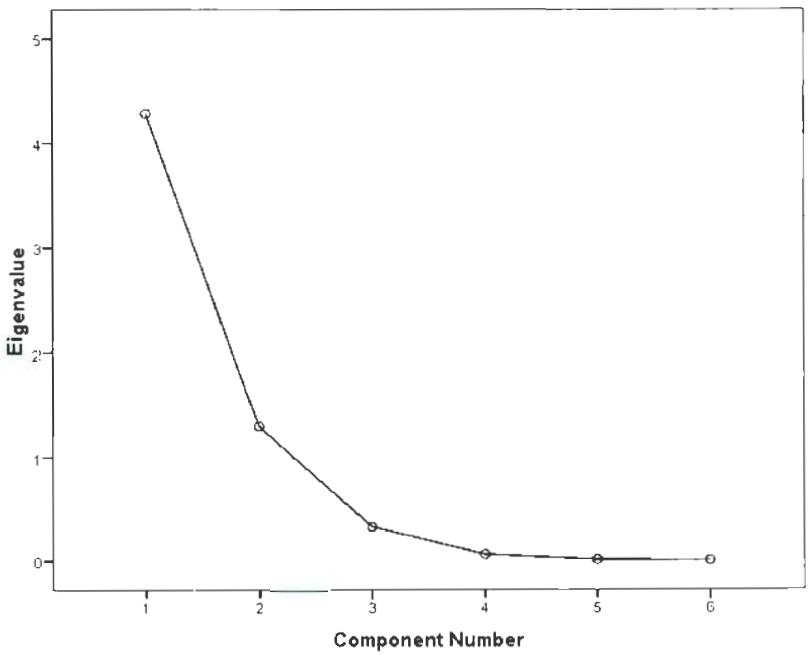

Figure B.23: Screeplot for Sm, Eu, Gd, Tb, Ho, and Er

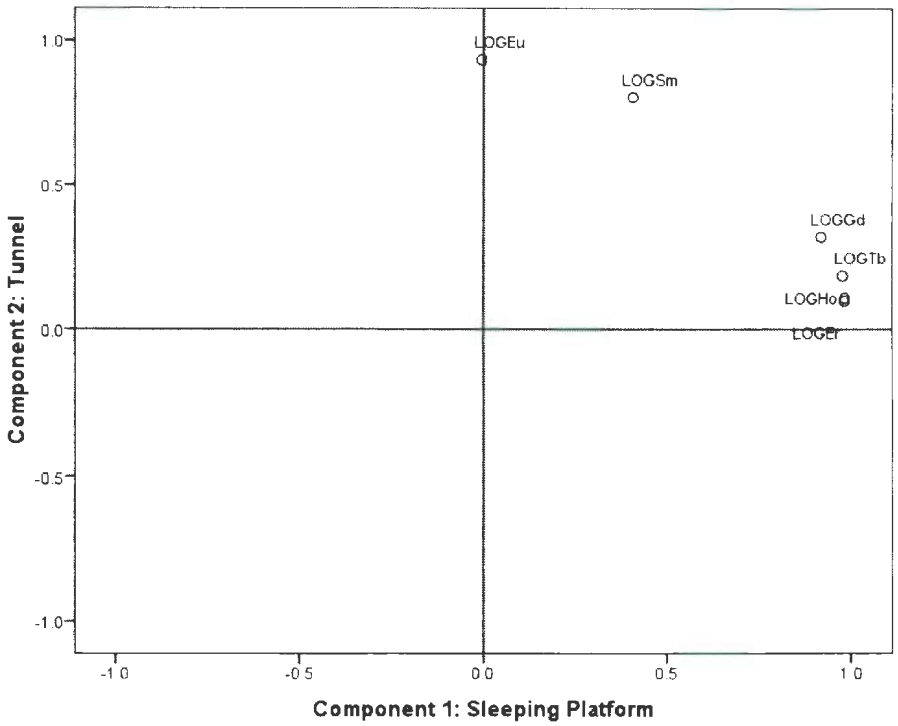

Figure B.24: Rotated Component Loading Plot for Sm, Eu, Gd, Tb, Ho, and Er

Table B.26: Correlation Matrix for Dy, Tm, Yb, Lu, Ta, and Th

		LOGDy	LOGTm	LOGYb	LOGLu	LOGTa	LOGTh
Correlation	LOGDy	1.000	0.914	0.968	0.953	-0.118	0.025
	LOGTm	0.914	1.000	0.936	0.911	0.013	-0.173
	LOGYb	0.968	0.936	1.000	0.982	0.028	-0.108
	LOGLu	0.953	0.911	0.982	1.000	0.018	-0.050
	LOGTa	-0.118	0.013	0.028	0.018	1.000	-0.420
	LOGTh	0.025	-0.173	-0.108	-0.050	-0.420	1.000
Sig. (1-tailed)	LOGDy		0.000	0.000	0.000	0.240	0.441
	LOGTm	0.000		0.000	0.000	0.470	0.149
	LOGYb	0.000	0.000		0.000	0.433	0.260
	LOGLu	0.000	0.000	0.000		0.458	0.382
	LOGTa	0.240	0.470	0.433	0.458		0.004
	LOGTh	0.441	0.149	0.260	0.382	0.004	

Determinant =0.000

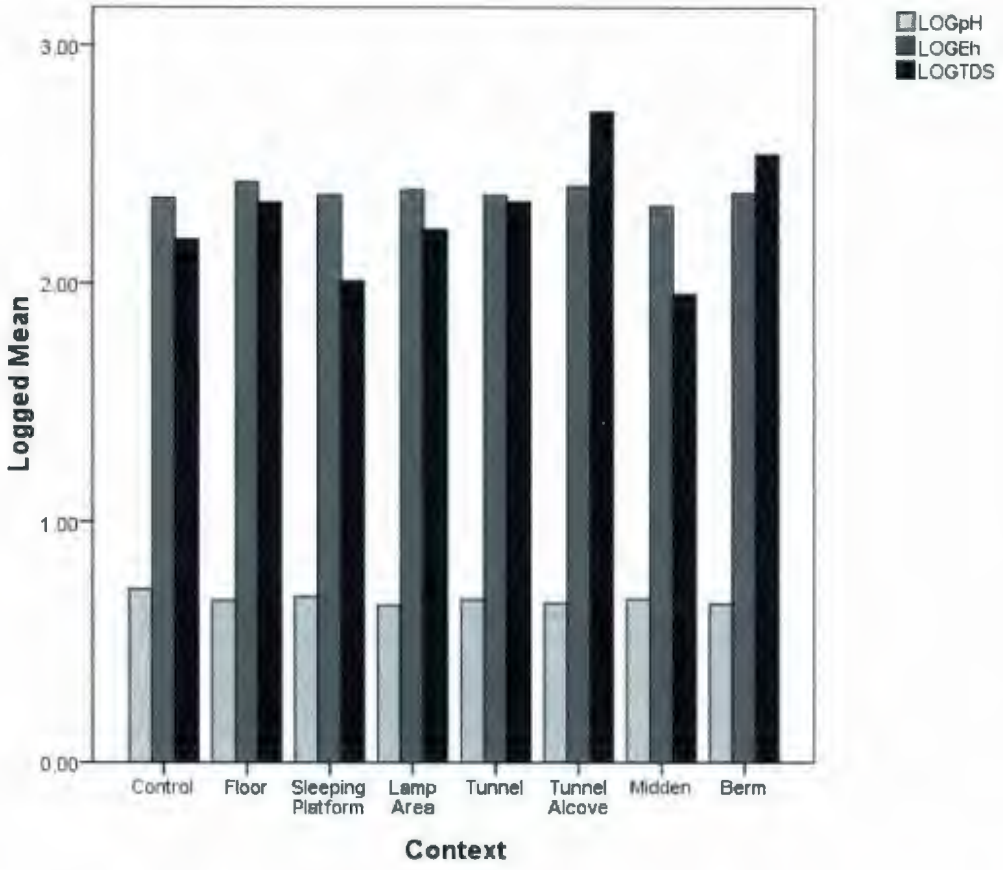

Figure B.25: Comparison of Logged Means for pH, Eh, and TDS

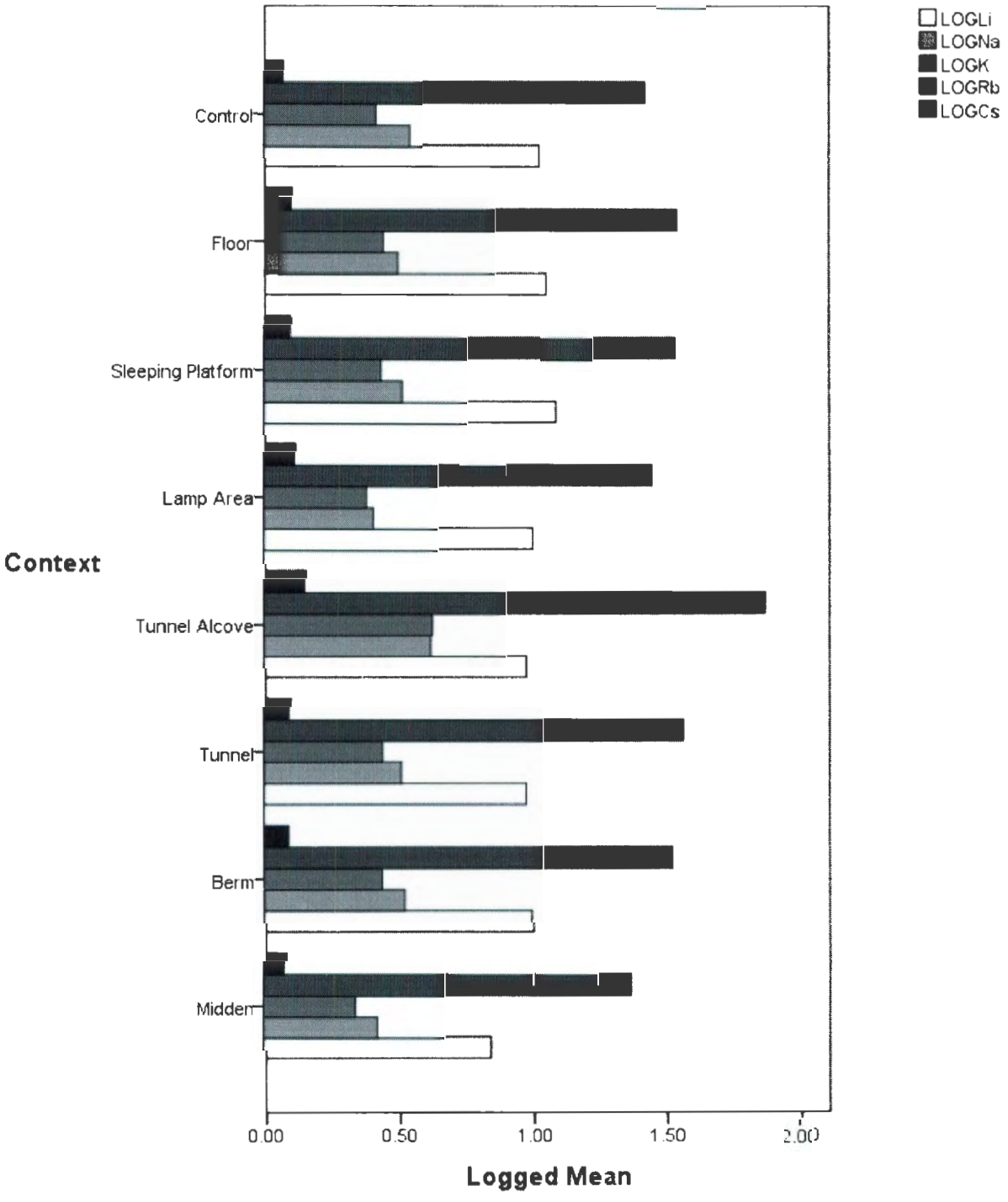

Figure B.26: Comparison of Means for Li, Na, K, Rb, and Cs

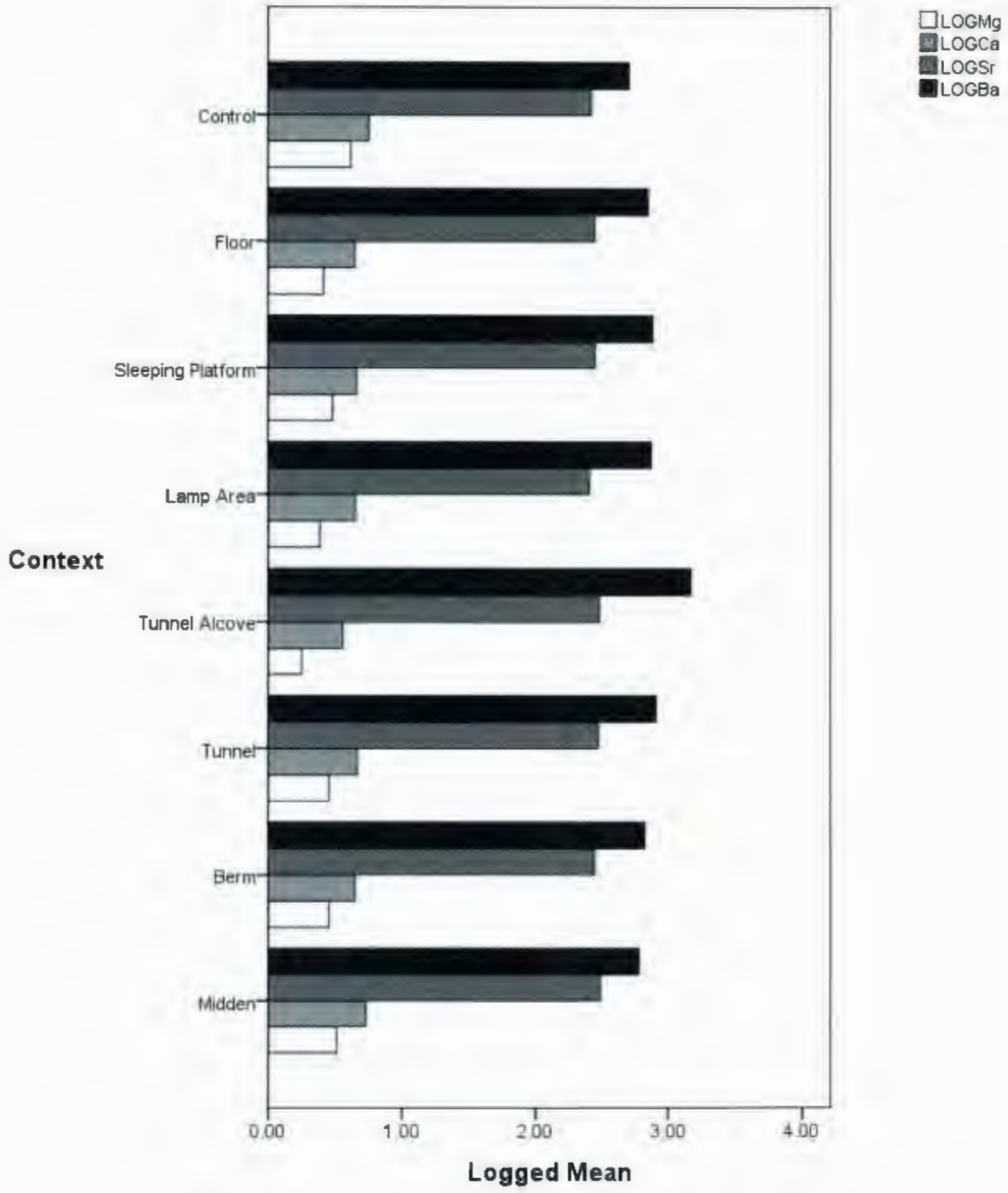

Figure B.27: Comparison of Means for Mg, Ca, Sr, and Ba

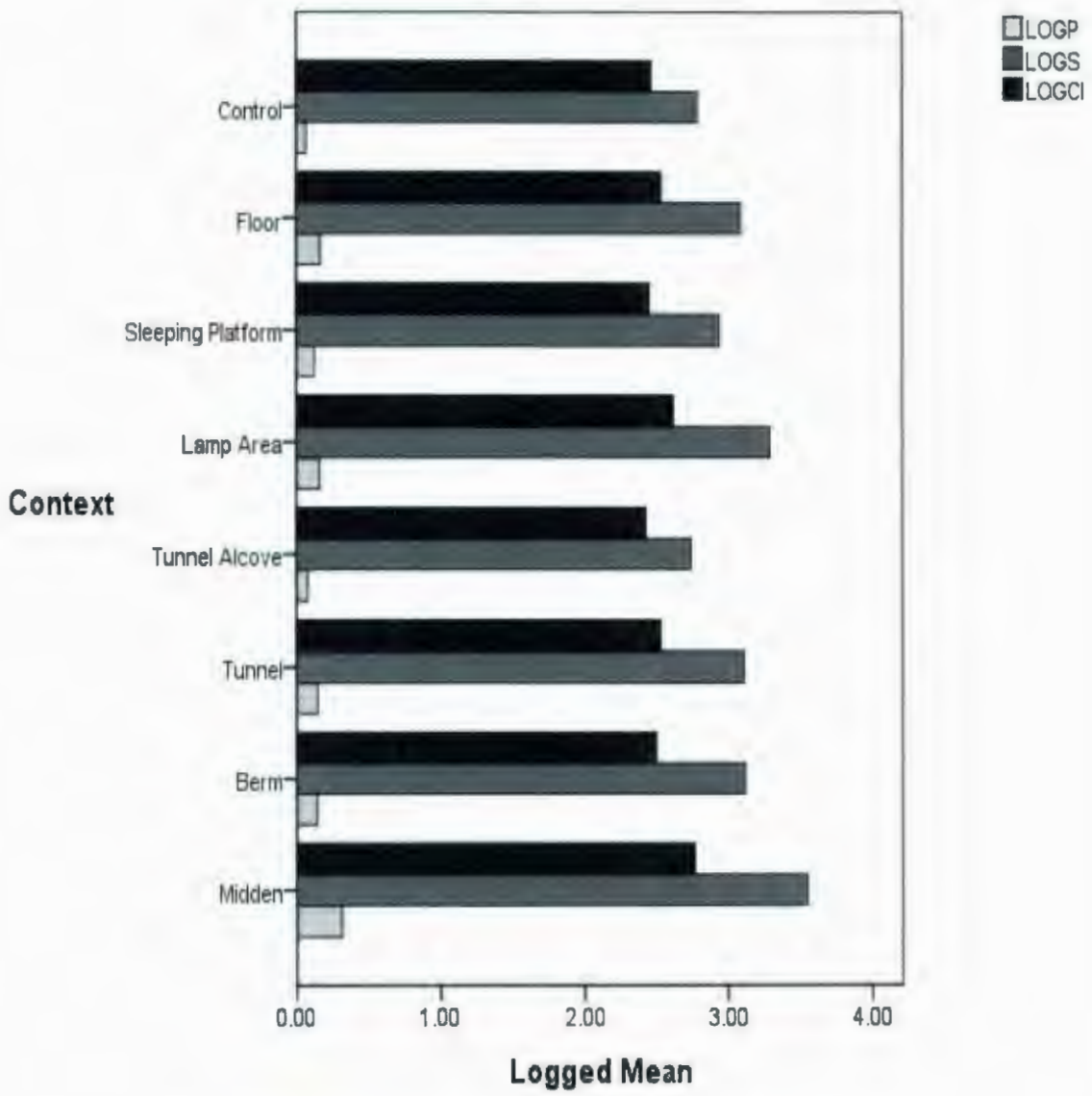

Figure B.28: Comparison of Means for P, S, and Cl

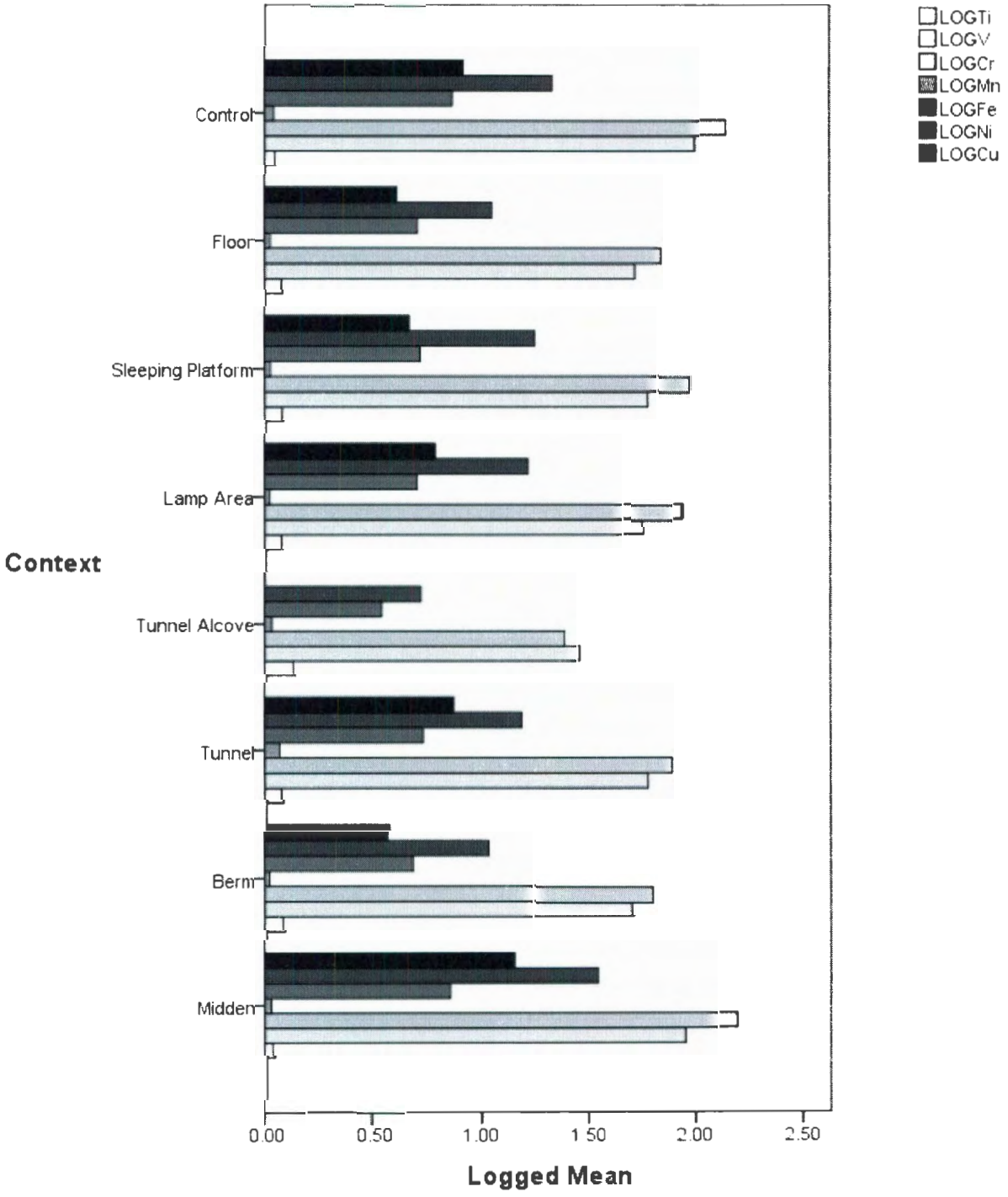

Figure B.29: Comparison of Means for Ti, V, Cr, Mn, Fe, Ni, and Cu

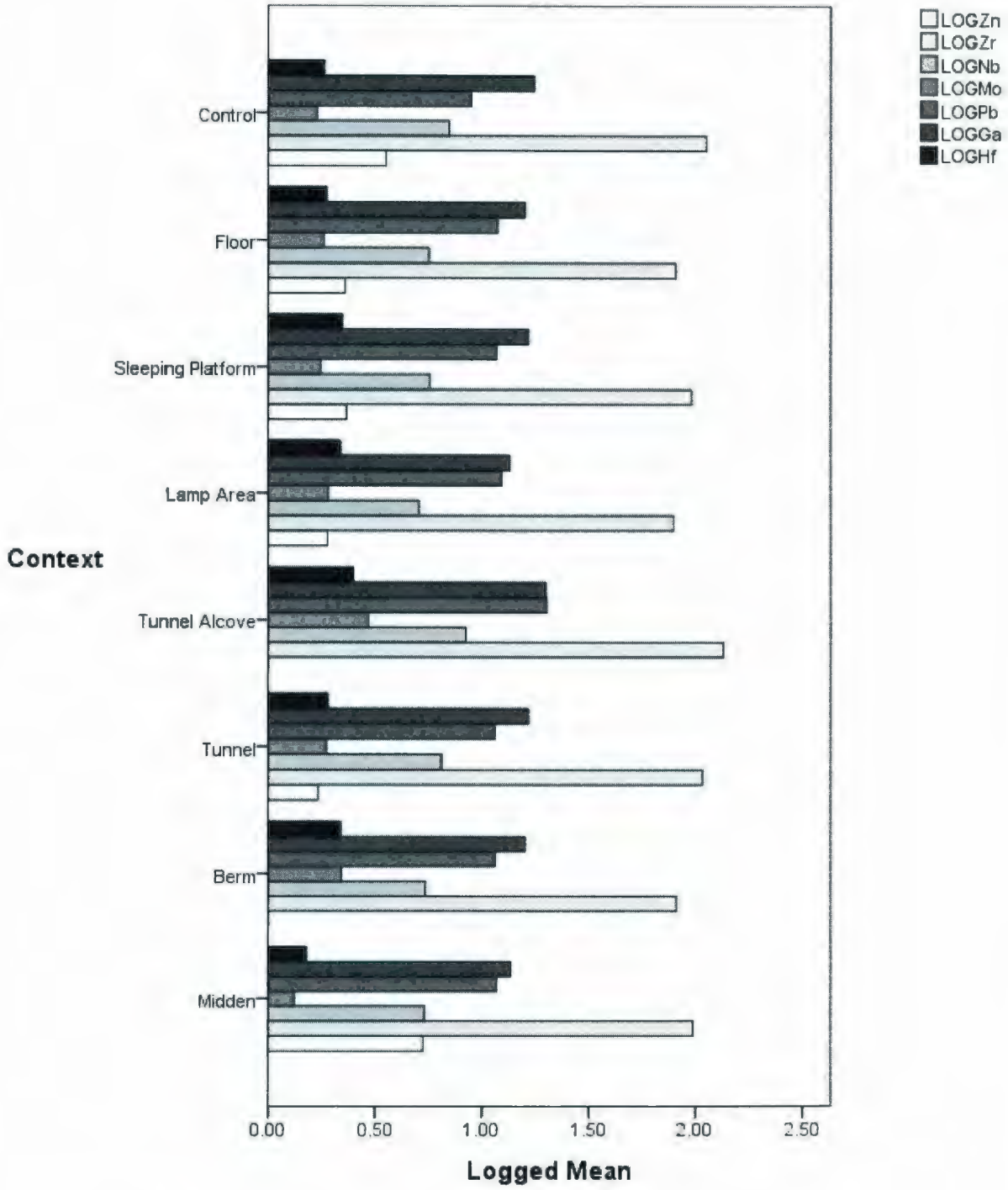

Figure B.30: Comparison of Means for Zn, Zr, Nb, Mo, Pb, Ga, and Hf

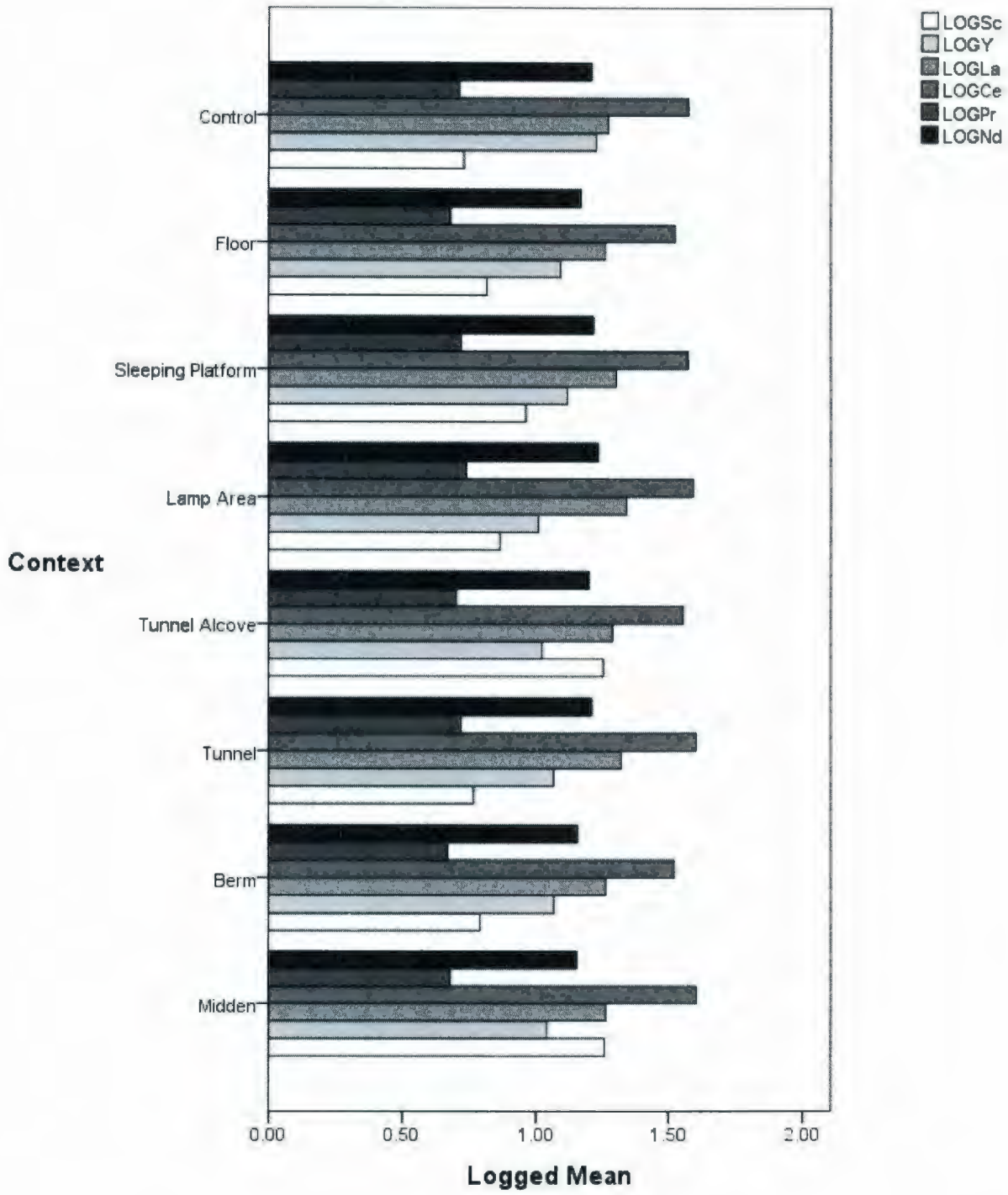

Figure B.31: Comparison of Means for Sc, Y, La, Ce, Pr, and Nd

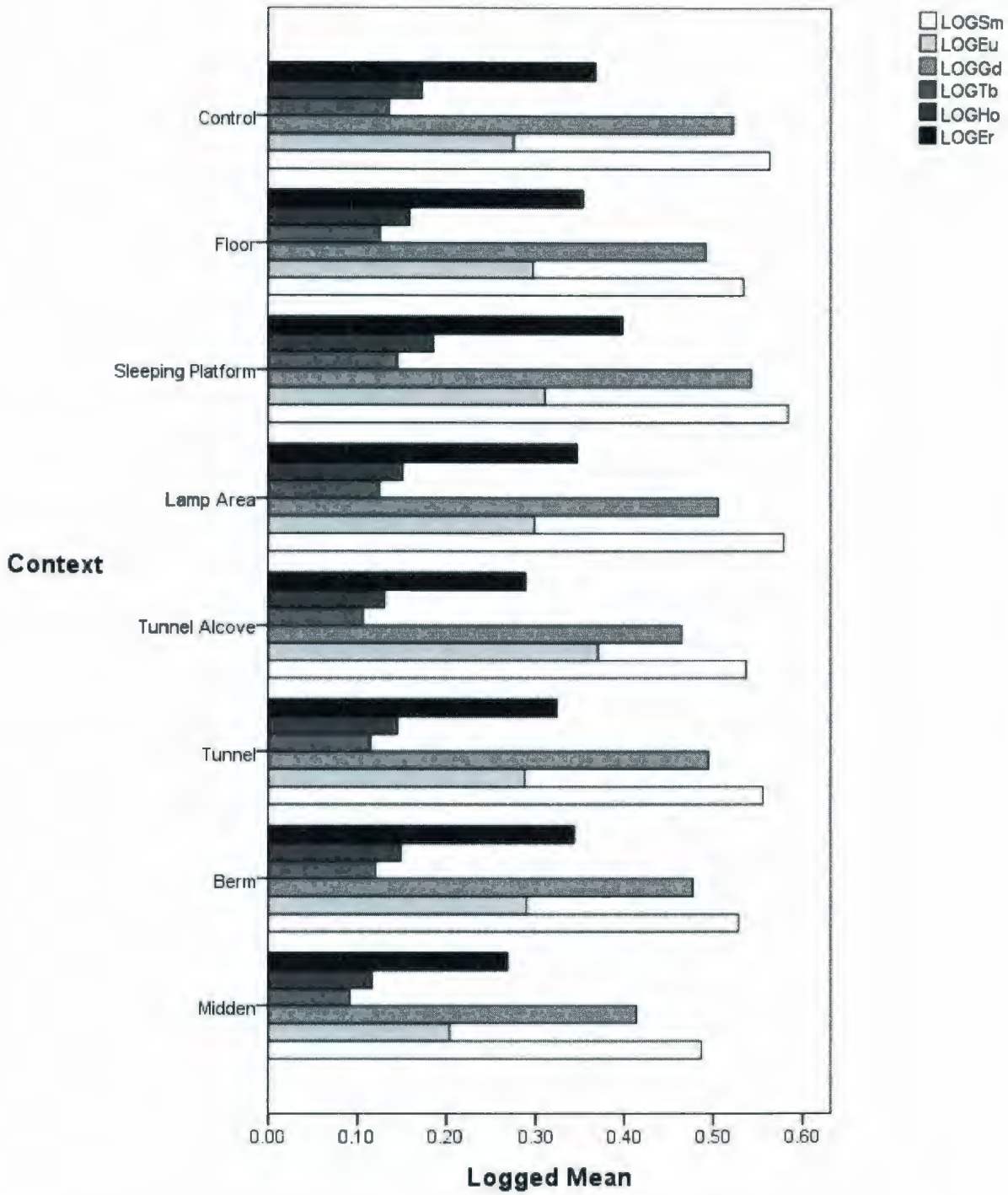

Figure B.32: Comparison of Means for Sm, Eu, Gd, Tb, Ho, and Er